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RCRA FACILITY INVESTIGATION
FINAL REPORT—PHASE I

NAVAL AIR STATION OCEANA
VIRGINIA BEACH, VIRGINIA

Prepared for:
ATLANTIC DIVISION NAVAL FACILITIES
ENGINEERING COMMAND
Norfolk, Virginia

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Glossary

AWQC	ambient water quality criteria
BTEX	benzene, toluene, ethylbenzene, and xylenes
CBPAO	Chesapeake Bay Preservation Area Ordinance
CMS	corrective measures study
CRDL	contract-required detection limit
1,1-DCE	1,1-dichloroethylene
1,2-DCE	1,2-dichloroethylene
1,1-DCA	1,1-dichloroethane
DRMO	Defense Reutilization Management Office
EA	environmental assessment
EPA	U.S. Environmental Protection Agency
HEA	health and environmental assessment
IAS	initial assessment study
IRP	Installation Restoration Program
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
mg/kg	milligrams per kilograms
mg/l	milligrams per liter
μg/kg	micrograms per kilogram
μg/l	micrograms per liter
MSL	mean sea level

MS/MSD	matrix spike/matrix spike duplicate
NAS	naval air station
NOAA	National Oceanographic and Atmospheric Administration
NPDES	National Pollution Discharge Elimination System
NWI	National Wetlands Inventory
OVA	organic vapor analyzer
OVM	organic vapor monitor
PAHs	polynuclear hydrocarbons
PCBs	polychlorinated biphenols
ppb	parts per billion
ppm	parts per million
QC	quality control
RBC	risk-based concentration
RCRA	Resource Conservation and Recovery Act
RFA	RCRA facility assessment
RFI	RCRA facility investigation
RMA	resource management area
RPA	resource protection area
SEABEEs	Naval Construction Battalion
SVOCs	semivolatile organic compounds
SWMU	solid waste management unit
TCE	trichloroethylene
TOC	total organic carbon

TPH	total petroleum hydrocarbons
TPV	total petroleum volatiles
USFWS	U.S. Fish and Wildlife Service
UST	underground storage tank
VOCs	volatile organic compounds
VPDES	Virginia Pollution Discharge Elimination System
VSI	visual site inspection

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Executive Summary

This report presents the results of a RCRA Facility Investigation (RFI) of 17 individual sites at NAS Oceana in Virginia Beach, Virginia. The purpose of the RFI was to investigate each site to determine the extent of contamination and estimate the potential threat to human health and the environment from known concentrations of chemical constituents. Field activities included an ecological study of each site; monitoring well installation; sampling of soil, sediment, surface water, and groundwater; and *in situ* hydraulic conductivity measurements. The data obtained during this investigation are presented along with data from previous investigations to give historical context and to support recommendations for each site. The sites fell into four recommended action categories:

1. **Advance to CMS.** Sites that are sufficiently characterized and have contamination that warrants a corrective measures study (CMS) of potential remediation options, even if some additional characterization is needed (Sites 1, 2B, and 2C).

2. **Continued RFI.** Sites that have contamination that has not been characterized sufficiently to either proceed to the CMS or reasonably rule out further action (Sites 2D, 2E, 15, and 25).

3. **Address Contamination.** Sites where the problem is characterized sufficiently, has contamination levels requiring action, and can be dealt with simply, without a CMS (Sites 11, 18, 19, and 20).

4. **No Further Study or Remediation.** Sites where investigation results do not indicate the need for additional study or consideration of remediation options (Sites 16, 21, 22, 23, and 26).

The data and analysis supporting the recommended action are presented in detail in Chapter 4.

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Chapter 1
Introduction

This report describes the Resource Conservation and Recovery Act (RCRA) Facility Investigation of the Naval Air Station (NAS) Oceana in Virginia Beach, Virginia, conducted by CH2M HILL from November 1992 to February 1993. The RCRA Facility Investigation (RFI) was a continuation of previous work done under the Navy's Installation Restoration Program (IRP) through 1988 and within a RCRA framework since 1990. Detailed elements of the investigation were set forth in the RFI Work Plan finalized in June 1992. This report describes in detail the RFI activities and results. Recommendations for future environmentally related activities are also included.

NAS Oceana Operations

NAS Oceana has been in existence since 1940 when it was established as a small auxiliary airfield. Since 1940, NAS Oceana has grown to more than 16 times it original size and is now a 6,000-acre master jet base supporting a community of more than 9,100 Navy personnel and 11,000 dependents. The primary mission of NAS Oceana is to provide the personnel, operations, maintenance, and training facilities to ensure that fighter and attack squadrons on aircraft carriers of the U.S. Atlantic Fleet are ready for deployment. A total of 62 squadrons, tenants, and nonnaval units are assigned to Oceana, including 12 F-14 Tomcat fighter squadrons and 7 A-6 Intruder medium attack squadrons.

In later 1981, NAS Oceana initiated a comprehensive hazardous waste collection and recycling program to prevent releases of hazardous wastes to the environment. The program involved constructing waste controls such as oil and water separators near aircraft cleaning and maintenance areas, and working closely with various shops to ensure that wastes were properly contained, segregated, labeled, and collected. NAS Oceana also monitors discharges within drainages on and off the station as part of its National Pollution Discharge Elimination System (NPDES) monitoring to prevent the discharge of contamination beyond the limits of the station.

Previous Studies

Three previous studies under the RI and two studies within the RCRA corrective action process were conducted at Oceana before the RFI. The IRP was designed to identify and correct problems of environmental contamination caused by past operations at naval facilities. The first stage of the Installation Restoration program at NAS Oceana was the completion of an Initial Assessment Study (IAS) in 1984 (RGH, 1984). The IAS recommended field investigations for six sites at NAS Oceana to confirm whether hazardous constituents had been released to the environment. In response to the IAS, the Round I Verification Study was performed in 1986 (CH2M HILL, 1986), and the Line Shack Site Inspection followed in 1988 (CH2M HILL, 1989). The Line Shack inspection focused on the areas around Line Shacks 130 and 400, which are Sites 2B and 2C, respectively. Complete descriptions of individual site histories are included in Chapter 4.

Application of RCRA corrective action began in June 1988, when U.S. Environmental Protection Agency (EPA) contractors conducted a RCRA Facility Assessment (RFA) of the base. The RFA identified all sites previously studied under the IRP as solid waste management units (SWMUs). Several additional SWMUs were identified and reviewed during the RFA. According to RCRA protocol, an RFI should follow the RFA when known or potential contamination warrants further study. The RFI of several sites at Oceana is being conducted as specified in a RCRA 3008(h) corrective action order, dated March 1990.

Before initiating a full-scale RFI, CH2M HILL conducted an Interim RFI in August 1990 to guide the RFI's scope of work. The Interim RFI continued the investigation of six sites, which were originally studied under the Navy's IRP, and also initiated work at four other sites. The field activities were oriented towards guiding a decision on whether a given site should be included for study under the RFI. The Interim RFI recommended additional work at most of the 10 sites studied, but at four sites, no further investigation was recommended.

Regulatory Framework

A total of 60 sites were recommended for study in the draft Consent Order issued by the U.S. Environmental Protection Agency. After considering the results of the Interim RFI, clarifications of site conditions by the Navy, and negotiations between the Navy and the EPA, the court reduced the list of RFA SWMUs to be studied under the RFI to 19.

Because of the proximity of four of the RFA SWMUs, they were consolidated into two RFI SWMUs with the result that 17 RFI SWMUs were designated for additional study in the final Consent Order between the Navy and the EPA, dated March 1990. Table 1-1 is a list of the RFA sites studied during the RFI. Figure 1-1 shows the location of each SWMU. The RFI SWMUs will be referred to as "sites" in this report.

The Consent Order specified four RCRA corrective action steps that would be required for the RFI sites. These were:

- Interim Measures, including the preparation of a community relations plan and other plans for future work
- The RFI
- A corrective measures study (CMS) to identify appropriate remediation technologies and approaches to remediate sites that require cleanup
- A corrective measures implementation of the selected remedies

Table 1-1
RCRA SOLID WASTE MANAGEMENT UNITS STUDIED IN THE RCRA FACILITY INVESTIGATION
NAVAL AIR STATION, OCEANA

RFI SWMU No.	RFA SWMU No.	Description
1	57	West Woods Oil Disposal Pit
2b 2c 2d 2e	51-54	Line Shack 130-131 Line Shack 400 Line Shack 125 Line Shack 109
2e	1	Hazardous Waste Storage Area, Bldg. 23
11 26	62,63,65	Fire Fighting Training Ring Fire Fighting Burn Pit, Bldg. 220
15	58	Abandoned Tank Farm, Old CPO Club
16 16GC	95	Pesticide Storage Area, Bldg. 821 Golf Course Support Facilities
18	3	Hazardous Waste Storage Area, Bldg. 204
19	71	Waste Oil Storage Areas, Bldg. 541
20	72	Waste Oil Storage Areas, Bldg. 543
21	97	Transformer Storage Yard, Bldg. 830
22	22	Construction Debris Landfill
23	78	Bowser, Bldg. 830
24	79	Bowser, Bldg. 840
25	25	Inert Landfill

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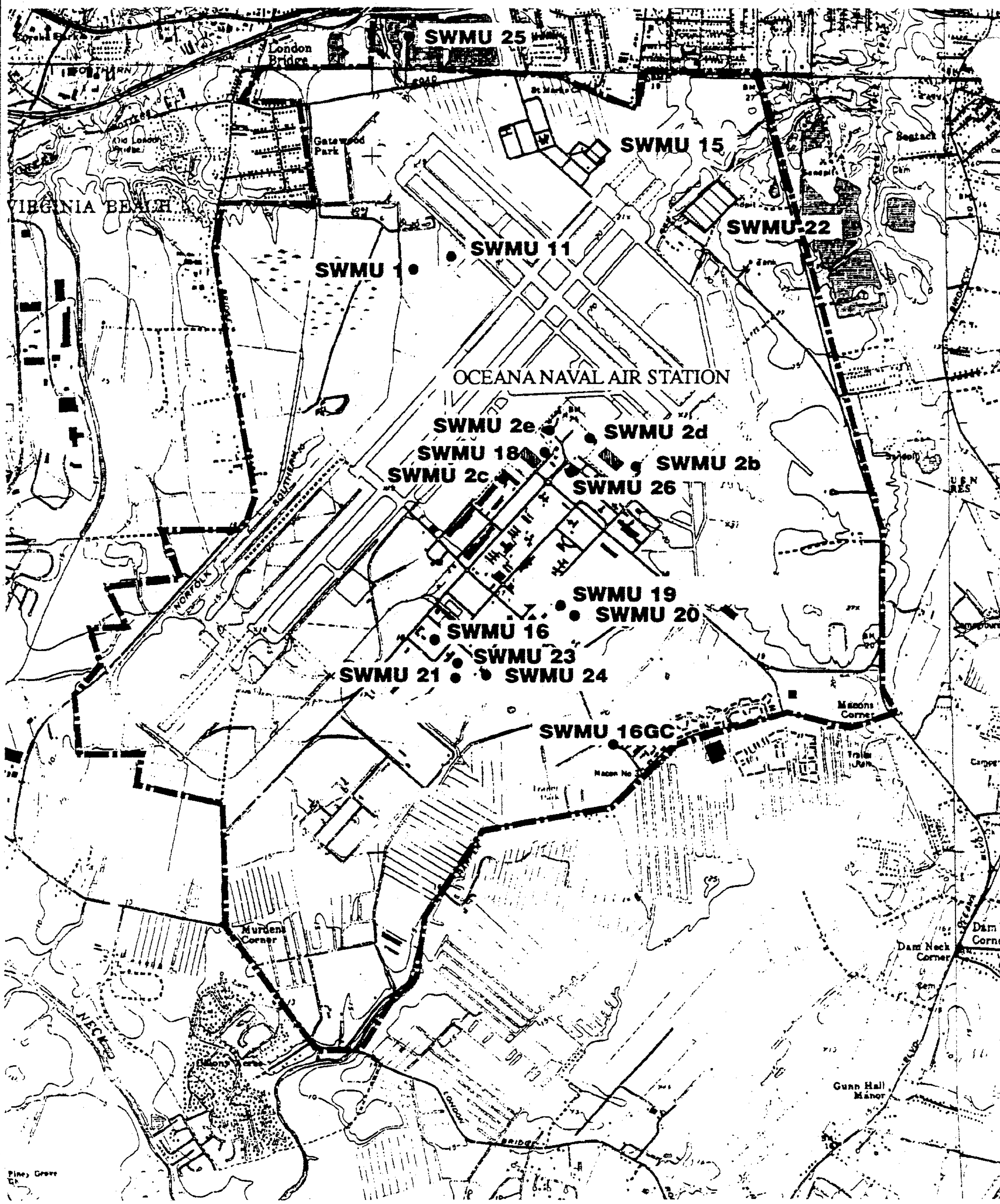

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Figure 1-1
LOCATIONS OF SWMUs
RCRA Facility Investigation–Naval Air Station, Oceana

RFI Activities

The RFI includes the study of site characteristics and contamination at each of the 17 RFI sites. These activities included drilling and installing wells; sampling soil, sediment, surface water and groundwater; surveying; conductivity measurements; and an ecological study. The ecological study was an important component of the RFI designed to determine the current ecological status of each site. The ecological study had two components: (1) a detailed study of the ecological setting of each site, and (2) an environmental assessment of the contaminant data collected during the RFI. The ecological assessment is a component of the health and environmental assessment (HEA) done for each site. Both elements are described in detail in Appendix A.

Report Organization

This report is divided into four chapters and nine appendices. Chapter 2 describes the environmental setting of NAS Oceana. It includes several elements of the ecological study mentioned above, particularly information on the general ecology and potential receptors. Chapter 3 summarizes field and data management activities during the RFI and gives some details about the general analytical program of the RFI. Most elements of Chapter 3 are described in detail in the appendices. Chapter 4 presents the main body of results of the RFI. Each site is described in detail as a separate entity in Chapter 4. The results are described in consecutive sections for each site as follows:

- Site location and history
- Past investigations and RFI site activities
- Environmental setting
- Contamination and extent
- Health and environmental and assessment
- Fate and transport
- Recommendations for future action

The appendices constitute a substantial body of pertinent information rather than a compilation of raw data. In particular, readers are encouraged to review the ecological description and assessment in Appendix A before reviewing the health and environmental sections in Chapter 4. Alternatively, Appendix A can be referred to repeatedly for clarification. Appendices B, C, and D present results from *in situ* groundwater sampling, drilling, and general field sampling. Soil boring logs are presented in Appendix C and field parameter data are presented in Appendix D. Appendix E presents the results and data plots of *in situ* hydraulic conductivity measurements. Appendix F presents miscellaneous field activities such as surveying, drum handling, and wastewater disposal. Appendix G is a report on data validation and Appendix H presents tabulated results of "pre-CMS" samples. These samples were collected during the RFI at the request of the Navy to allow some initial screening of corrective measure technologies early in the CMS.

Chapter 2
Environmental Setting

Introduction

A comprehensive description of the land use, climate, topography, surface water hydrology, soils, wetlands, plant and animal species, and cultural resources of NAS Oceana is presented in this chapter. The following sections provide an overview of the environmental setting and the potential receptors that have been observed or could occur within and adjacent to the station.

Location and Land Use

NAS Oceana is in the Tidewater region of Virginia. The station lies southeast of Norfolk, immediately west of the Atlantic Ocean, and just south of the Chesapeake Bay. Oceana consists of approximately 6,000 acres within the city of Virginia Beach as seen on Figure 2-1. Land use surrounding the station consists primarily of residential, commercial and transportation-related development. Land use is generally geared toward facilitating the use of available space for conducting air operations. The installation has ongoing programs for recreation, forest management, and agricultural lease. Figure 2-2 indicates land use in the area of the station.

Agriculture

Approximately 923 acres at Oceana are farmed by private producers under the Navy's agricultural outlease program (Nair, 1988). Major crops grown within the boundaries of the station are corn, soybeans, and winter wheat.

Urban and Other Areas

More than 40 percent of the Oceana property is occupied by commercial, residential, and station operations buildings, or is open space among the runways, hangars, and similar structures (Nair, 1988). Urban areas on the station are intensively maintained and include mowed lawn and horticultural plantings. Other areas on the station include recreational facilities: golf course (225 acres), stables (43 acres), and a skeet range (50 acres) (Nair, 1988).

Climate

NAS Oceana is near the Atlantic Ocean, which accounts for the mild year-round temperatures. The Virginia Beach-area climate is characterized by hot, humid summers

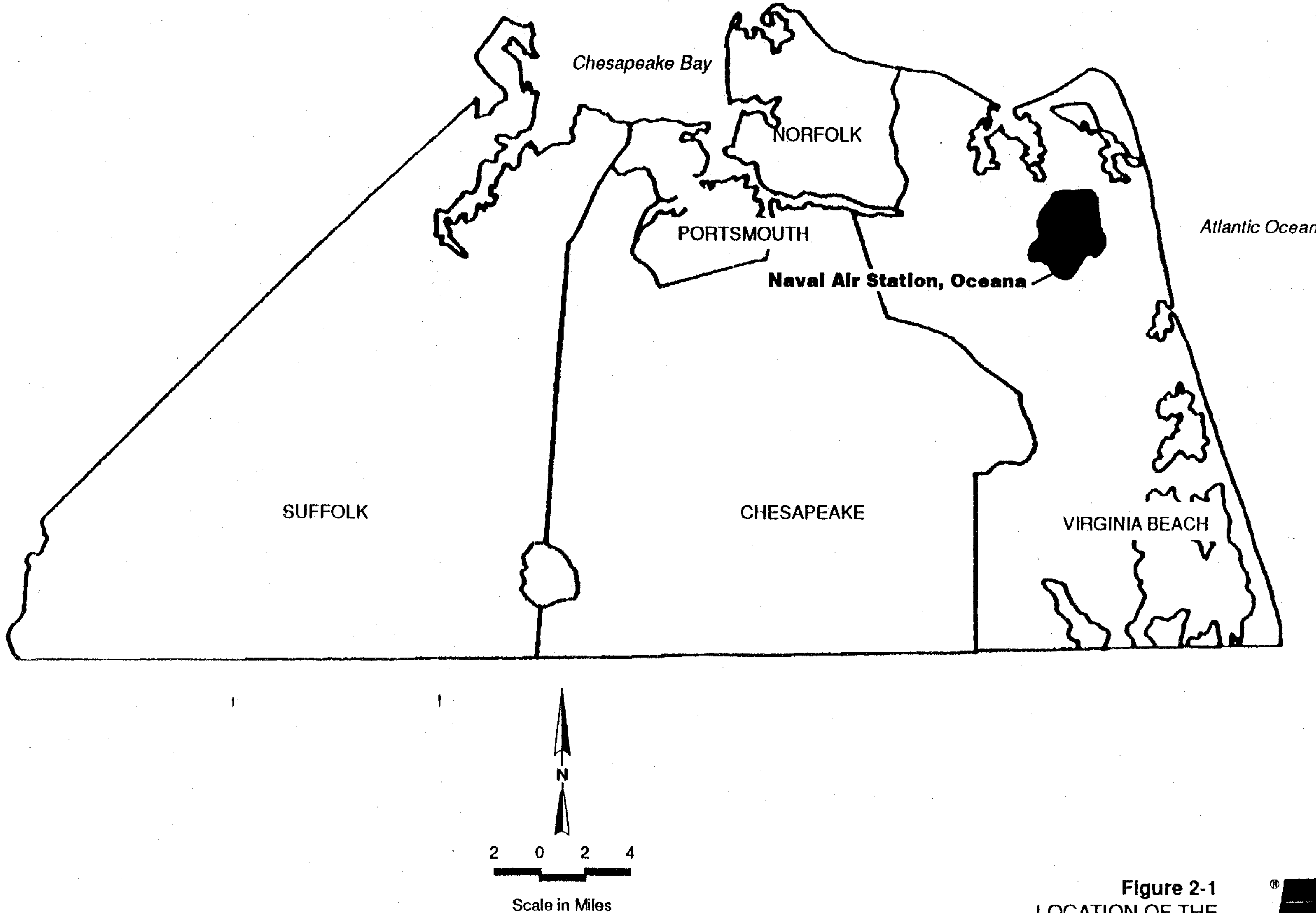

Figure 2-1
LOCATION OF THE
NAVAL AIR STATION, OCEANA

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and mild winters. The annual average temperature is 68.2°F with an average annual precipitation of 44.62 inches. Seasonal snowfall is approximately 7 inches annually (DNH, 1990). Average windspeed at the station is approximately 10 mph (DNH, 1990). Coastal storms, in the form of severe thunderstorms, northeasters, and hurricanes frequently impact the station.

Topography and Surface Water Hydrology

The elevation of the station ranges from approximately 5 feet above mean sea level (MSL) in the drainage ditches to approximately 25 feet above MSL in the open fields. Elevations in the developed area of the station range from 10 to 25 feet above MSL. Topography of the station is generally flat with a general easterly slope to the land surface.

Surface runoff from the station is facilitated by a system of drainage ditches and surface canals that flow south and west to West Neck Creek, north to London Bridge and Great Neck Creek, and east to Owls Creek and Lake Rudee. Figure 2-3 indicates surface hydrology and drainage ditches at the station. The presence of iron precipitate, organic odors, high turbidity, and thick brown algae mats in many ditches was noted during the field investigation.

Several borrow ponds exist in and near Sites 22 and 25. The ponds are mostly shallow, with a few deep areas. Water quality in the sand pit ponds is marginal for good fish production because of low alkalinity, hardness, and pH (USFWS, 1990). Eutrophication, reduced dissolved oxygen, and algae blooms occur during most summers in the shallow ponds. However, these conditions do not appear to severely affect the system because fairly large fish populations exist in the ponds (Fishery Management Report, USFWS, 1990).

Regional Geology and Hydrogeology

NAS Oceana is on the outer edge of the Atlantic Coastal Plain physiographic province. The Atlantic Coastal Plain is a broad wedge of unconsolidated sediments that dip and thicken to the east. In the area of NAS Oceana the sediments consist of several thousand feet of unconsolidated sand, clay, silt, and gravel, and are underlain by granite basement rock. The sediments range in age from early Cretaceous to Recent. From oldest to youngest, the four geologic units are (1) the Potomac Formation, (2) Pamunkey Group, (3) the Chesapeake Group, and (4) the Columbia Group (Meng and Harsh, 1984). The Chesapeake Group has been differentiated further into several units, which are, from oldest to youngest, the Calvert, Choptank, St. Marys, Eastover, and Yorktown Formations. The Columbia Group sediments overlying the Chesapeake Group also have been differentiated into several units (Oaks and Coch, 1973).

The geologic units of concern in the environmental investigations at the NAS Oceana are the Yorktown Formation and the Columbia Group. The Yorktown Formation consists of interbedded layers of shelly, very fine to coarse sands, clayey sands and sandy clay. Shelly layers are common in the Yorktown (Meng and Harsh, 1984). Siudyla *et al.* (1981) divided the Yorktown into three sand units each overlain by a confining layer of silt and clay.

Regionally, the uppermost of these silt and clay beds, which is referred to as the Yorktown confining unit, separates the Yorktown Formation from the sediments of the Columbia Group that overlie it. This uppermost bed consists of massive, well-bedded yellow-gray to greenish-gray clays and silty clays, which commonly contain shells, fine sand, and mica. The clay layers within the confining bed are generally extensive but are a series of coalescing clay beds rather than a single deposited unit. This unit was deposited in a shallow open-marine environment of broad lagoons and quiet bays (Meng and Harsh, 1984). The Yorktown confining unit was not encountered while drilling at NAS Oceana.

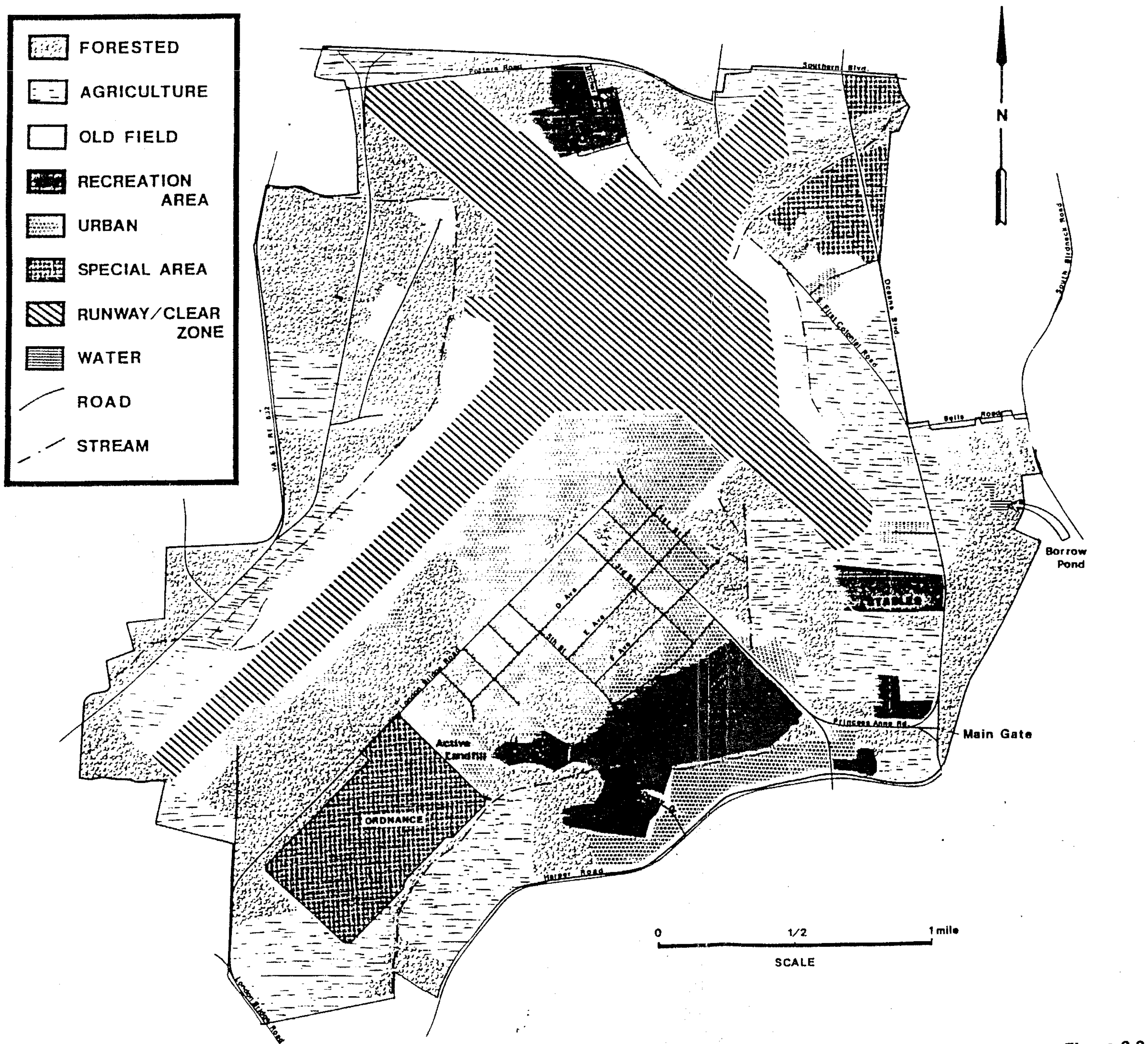
The sediments of the Columbia Group consist of interbedded gravel, sands, silts, and clays of Pleistocene and Holocene age. The Pleistocene and Holocene sediments were deposited in fluvial-marine terrace and near-shore marine environments, including lagoons, beaches, tidal flats and barrier islands (Oaks and Coch 1973; Hamilton and Larson, 1988).

The Columbia Group sediments are, from oldest to youngest, (1) the Great Bridge Formation, (2) the Norfolk Formation, (3) the Londonbridge Formation, and (4) the Sand Bridge Formation (Oaks and Coch, 1973). These formations are differentiated in Figure 2-4.

The Sand Bridge Formation consists of a pale, yellowish-brown silt to sandy silt, often characterized as being clayey. This formation extends from the surface to a depth of three to six feet. Underlying the Sandbridge Formation is the Londonbridge Formation, a bluish-gray, fine silty sand, which is generally four to five feet thick.

The third member of the Columbia Group encountered while drilling at the NAS, Oceana is the Norfolk Formation. This formation, which is approximately eight to eleven feet thick, is a bluish-gray to gray, fine to medium sand with trace shell fragments. The Great Bridge Formation underlies the Norfolk. The Great Bridge has an upper and lower member. The upper member is a white to light gray, well-graded sand. The lower member exhibits similar grain sizes and colors, but contains minor amounts of pebble gravel and bluish shell fragments. The Great Bridge Formation ranges in thickness from 0 to 55 feet.

Groundwater at NAS Oceana is generally within 4 to 10 feet of the land surface. Aquifer conditions are unconfined in the Columbia Group and unconfined to semiconfined within the upper Yorktown Formation (Siudyla *et al.*, 1981). When the clay confining unit overlying the Yorktown is absent, the upper Yorktown is generally unconfined. Natural groundwater flow directions are generally south to southeast, but flow direction is



Source: Nair, 1988.

Figure 2-2
LAND USE/COVER
NAVAL AIR STATION, OCEANA

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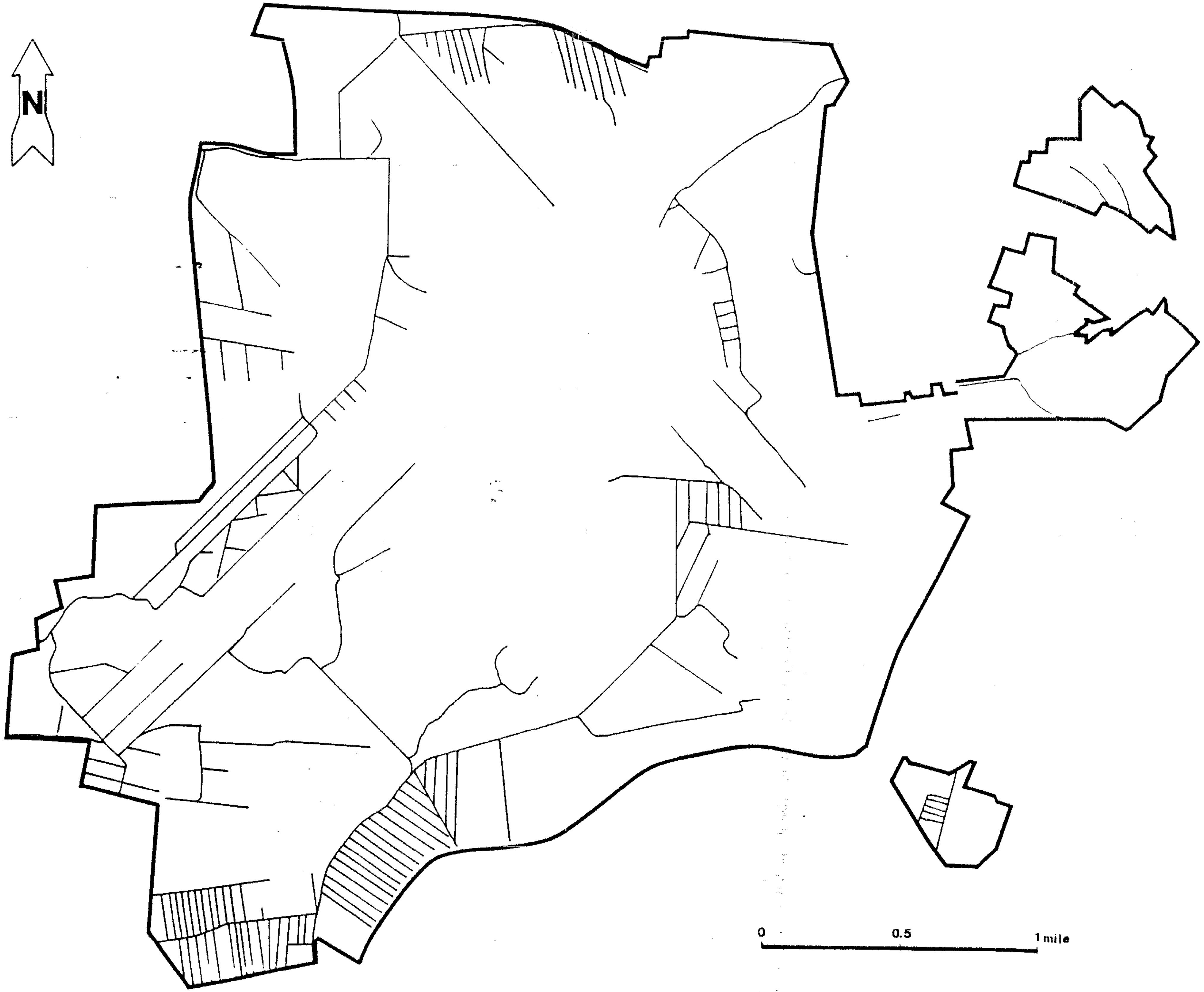

Source: Nair, 1988.

Figure 2-3
SURFACE WATER HYDROLOGY
NAVAL AIR STATION, OCEANA

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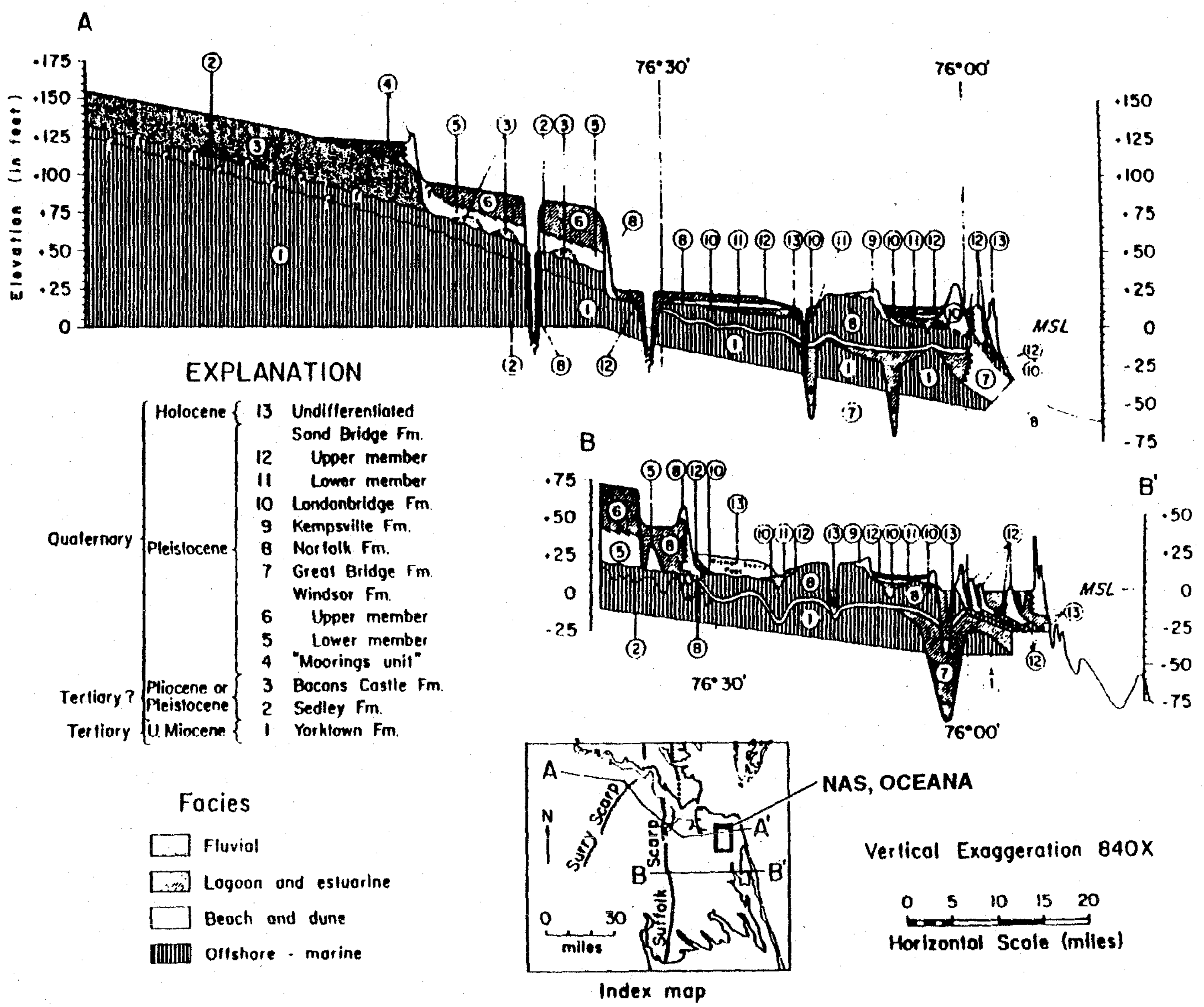

Figure 2-4
CROSS-SECTION OF POST-YORKTOWN GEOLOGIC UNITS UNDERLYING NAS, OCEANA

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controlled locally by drainage ditches. The flow direction in the Virginia Beach area is therefore highly variable because of the complexity of the drainage patterns. Groundwater from the Columbia Group sediments is not used in the area of NAS Oceana.

Cultural and Historical Resources

History of NAS Oceana

The earliest probable use of the Oceana NAS site was by nomadic hunter-gatherers of the prehistoric Archaic Period (8000-1000 B.C.) (RGH, 1984). From 1000 B.C. until European contact, woodland indians inhabited coastal Virginia. These people erected semipermanent villages and farms and exploited marine resources from temporary camps on the coastal beaches and dunes (RGH, 1984).

English settlers arrived in the area in the early 1600s. By the mid-17th century, and until the Civil War, coastal Virginia remained an agricultural area, with an economy that was based on plantations, slaves, and tobacco farming. With the end of the Civil War came the end of the plantation system and slavery. Tidewater Virginia's economy changed to smaller farms and marine resources exploitation (RGH, 1984).

In 1940 the United States Navy purchased 329 acres at Virginia Beach for an auxiliary air station. During World War II the air field was expanded. After 1943 facilities were constructed to house a large-scale operation. After World War II, the first Navy jet airfield was opened at NAS Oceana. By 1970 NAS Oceana consisted of approximately 6,000 acres (Greenhorne & O'Mara, 1990).

Inventory of Historical Sites

The National Historic Preservation Act of 1966, as amended, requires identifying and protecting historical and archeological resources. An Historic and Archeological Resources Protection Plan for Oceana was completed in 1991. This report lists several structures with potential eligibility for being listed on the National Register of Historic Places.

No areas of historic or archeological interest on NAS Oceana are listed on the National Register of Historic Places (RGH, 1984; Greenhorne & O'Mara, 1990).

A recent (1989) archeological survey conducted by the U.S. Army Corps of Engineers concluded that two 18th-century houses formerly stood on Oceana property. The houses, Cornick House and the Salisbury Plains House, have been destroyed. These sites have archeological potential that may require an intensive survey to determine eligibility for the National Register (Greenhorne & O'Mara, 1990).

The Bell-Taylor House, circa 1810, now called the Admiral's House, is on Route 615 within the NAS. The house was reviewed by the State Historic Preservation Office and was determined to be eligible for the National Register (Hostetter, 1993). Several other areas with potential archeological resources will be surveyed before or during a complete stationwide study of structures and sites, which is proposed for late fiscal year 1993.

Ecology

Soils

Three soil mapping units, shown in Figure 2-5, dominate the soil types on the station: Udorthents-Urban Land, Bojac, and Acredale-Tomotley-Nimmo series (Soil Conservation Service, 1985). This soil series occurs on broad, flat areas and is a disturbed loamy soil that is well-drained or moderately well-drained. This mapping unit occurs in areas that have been altered during excavation or covered by fill material, or occurs in areas that are covered by buildings, runways, parking lots, and other structures.

Bojac fine sandy loam is deep, nearly level, and well-drained. This mapping unit occurs in low inland ridges and side slopes. The surface layer of this soil is typically dark brown, fine sandy loam to about 8 inches. The subsoil is 30 inches thick, dark brown fine sandy loam and loam. The substratum is mostly brownish-yellow and yellow, loamy fine sand and fine sand to a depth of at least 60 inches (SCS, 1985). Most areas of this soil are used for cultivating crops. Because the seasonal high-water table is approximately 4 to 6 feet, and permeability is rapid in the substratum, the soil is limited for community development use.

The Acredale-Tomotley-Nimmo series is a poorly drained hydric soil, with a loamy subsoil. This soil is formed in marine and fluvial sediments. Typically, the surface layer of soil is grayish-brown silt loam about 7 inches thick. The subsoil is 43 inches thick, mostly gray silt loam and silty clay loam. The substratum is mottled gray and yellowish-brown, fine sandy loam to a depth of at least 60 inches. The Acredale series are slowly permeable and have a seasonal high-water table of about 1 foot. Most areas of this soil have been drained for cultivating crops or building. Most of the station is covered in the Acredale series. These soils are typical of coastal plain soils of the Virginia Beach area.

The Tomotley and Nimmo soils are poorly drained soils that are moderately permeable and have a seasonal high-water table of about 1 foot. The Nimmo surface soil is typically dark gray loam about 7 inches thick. The subsoil is 26 inches thick, mostly light gray and gray, fine sandy loam and loam. The substratum is light gray fine sand to a depth of approximately 60 inches. The Tomotley series has a surface layer that is typically dark grayish-brown loam about 7 inches thick. The subsoil is about 38 inches thick, mostly gray and light brownish-gray, loam and sandy clay loam. The substratum is mottled, gray loamy sand to a depth of at least 60 inches. These soils occur on broad inland flats or shallow drainage ways. Most areas have been drained and are used for crops, woodlands, or community development.

A large portion of the soils at Oceana (49 percent) are classified as hydric (Nair, 1988). However, extensive artificial drainage maintains these lands for development or agriculture. Although much of the station has been artificially drained by ditches, many soils retain hydric characteristics. Most of the wettest soils occur in the forested areas of the station.

Vegetation and Wetlands

A wide variety of vegetation types occur at Oceana. Approximately 600 acres of forest and 200 acres of open land comprise the undeveloped areas at Oceana (RGH, 1984). Approximately 660 acres (11 percent) of the land area at NAS Oceana are wetlands (Oceana NAS, 1993). Table A-1 in Appendix A lists the plant species observed on the station during the onsite survey. The U.S. Fish and Wildlife Service (USFWS) wetland indicator status (Cowardin *et al.*, 1979) is given for each species. The indicator reflects the range of estimated probabilities of a species occurring in a wetland versus a nonwetland. The indicator categories are as follows:

- Obligate Wetland (**OBL**). Under natural conditions, occurs almost always in wetlands (estimated probability >99 percent), and seldom found in nonwetlands.

- Facultative Wetland (**FACW**). Usually occurs in wetlands (67 percent - 99 percent), but occasionally found in nonwetlands.

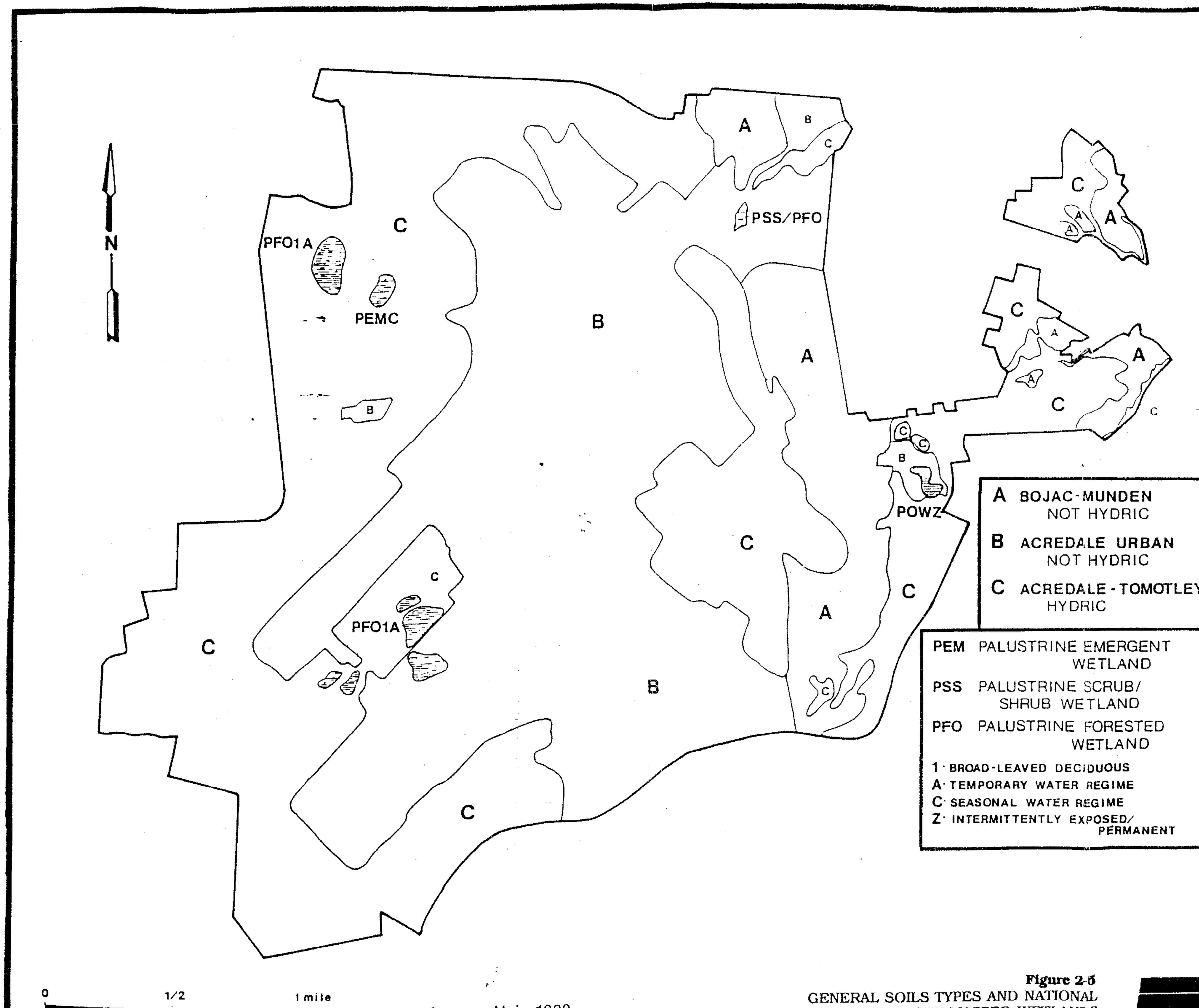
- Facultative (**FAC**). Equally likely to occur in wetlands or nonwetlands (34 percent to 66 percent).

- Facultative Upland (**FACU**). Usually occurs in nonwetlands (67 percent to 99 percent), but occasionally occurs in wetlands.

- Upland (**UPL**). Almost always occurs, under natural conditions, in nonwetlands (>99 percent).

The USFWS's National Wetland Inventory (NWI) maps indicate approximately 880 acres of wetlands on the station as palustrine (USFWS, 1991). In addition to the NWI mapped wetlands shown in Figure 2-6, onsite observations by the CH2M HILL ecologist indicate that much more of the existing forested areas on the station are palustrine wetlands than are shown on the NWI maps.

Most of the forested areas on the station are dominated by pine, mixed pine-hardwood, and hardwood stands. Areas with poorly drained, saturated soils are dominated by sweetgum, red maple, and, sometimes, loblolly pine. Most forested stands with unsaturated or moist soil conditions are dominated by loblolly pine or mixed pine-hardwoods. Upland forested areas usually have more oaks and cherry. Other overstory species likely to occur with these species are water oak, southern red oak, swamp chestnut oak, willow oak, tulip



Source: Nair, 1988.

Figure 2-5
GENERAL SOILS TYPES AND NATIONAL WETLANDS INVENTORY-MAPPED WETLANDS
NAVAL AIR STATION, OCEANA

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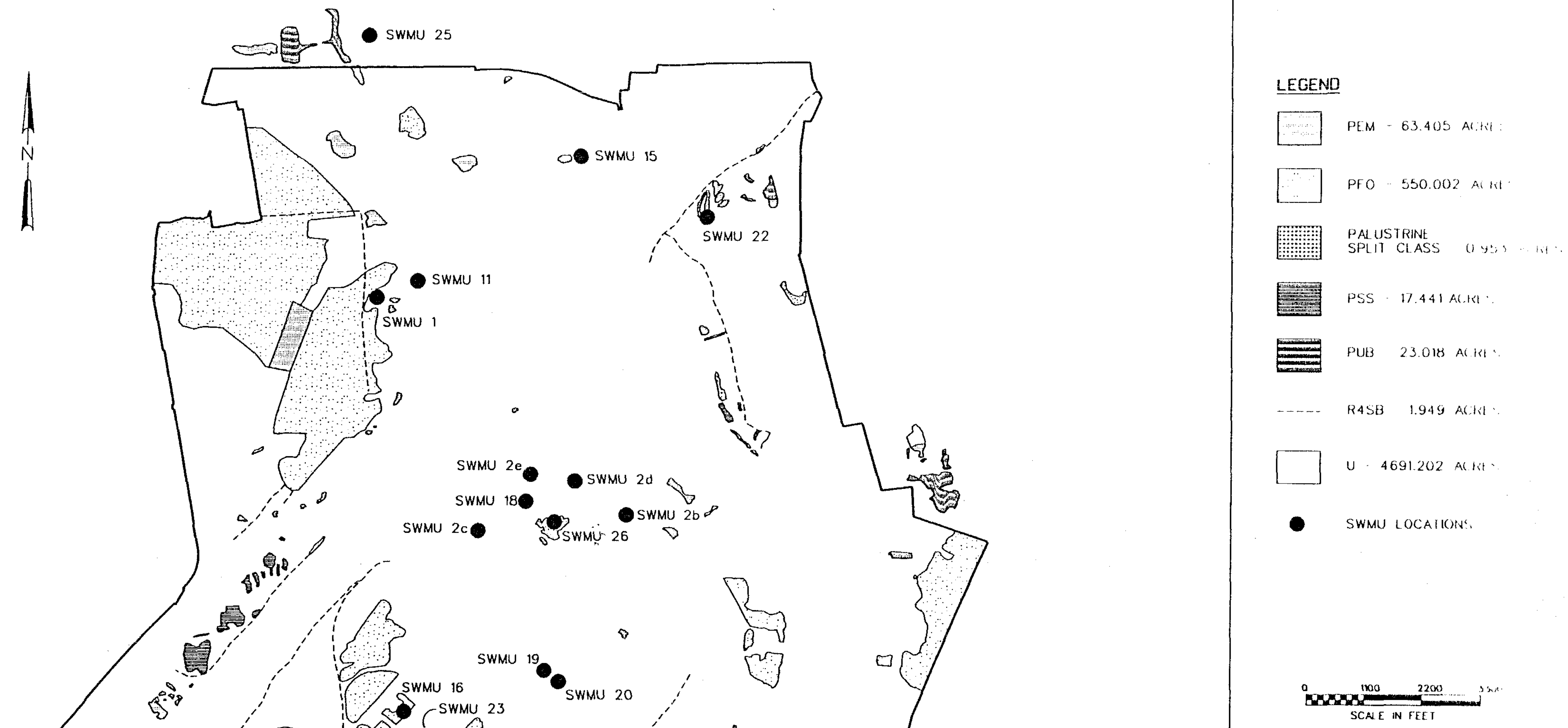

SOURCE: U.S. FISH AND WILDLIFE
DEPARTMENT OF THE

(WETLANDS DEPICTED BASED ON
INTERPRETATION AND NATIONAL
INDICATOR MAPS, PRINCESS ANNE

Figure 2-6
WETLANDS
NAS OCEANA

CH2M HILL

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poplar, and black gum. Understory vegetation in the hardwood stands is switch cane. Other species occurring in the hardwood understory inclu pawpaw, Japanese honeysuckle, and bayberry. Understory plants that com loblolly forests include sparse stands of switch cane, greenbriar, and Japanes Because of the season and the qualitative nature of the vegetative assessmen species observed on the station were identified. Appendix A contains a list likely to occur on Oceana.

Chesapeake Bay Preservation Area Ordinance

The Chesapeake Bay Preservation Area Ordinance (CBPAO) applies to all the Chesapeake Bay watershed within the city of Virginia Beach except fe The Virginia Beach CBPAO does not have jurisdiction over areas in however, the policy of the Department of Defense is for all federal inst Chesapeake Bay Region to comply voluntarily with state and local C preservation programs to the greatest extent feasible (Olson, 1993).

According to the Virginia Beach Planning Department, areas that may be r the CBPAO include resource protection areas (RPAs), which include components:

- Tidal wetlands
- Nontidal wetlands, which, under normal circumstances, are s ground surface and connected by surface flow and conti wetlands or tributary streams
- Tidal shores
- A 100-foot vegetated buffer area adjacent to and landward of t listed above, and along both sides of any tributary stream

The CBPAO requires a 100-foot buffer around perennial streams, ditches saturated wetlands within RPA-designated areas. Resource management consist of areas not designated as resource preservation areas. Oceana is RMA. RMAs and RPAs include lands types, which, if improperly used have the potential for significantly degrading water quality. The RMA protect the RPA areas, and extends inland to the watershed boundary.

Chapter 3
RFI Activities

Field Activities

General Description

CH2M HILL conducted the field investigation as part of this RFI from late November 1992 until mid-February 1993. Field activities include:

- An ecological study
- Hydraulic probe sampling
- Drilling and monitoring well installation
- Environmental sampling
- *In situ* hydraulic conductivity tests

The environmental sampling program included groundwater, soil, sediment, and surface water. Associated activities during the field investigation were surveying, drum handling, and groundwater collection and disposal.

This chapter is a brief synopsis of the RFI field activities. Table 3-1 summarizes the RFI field activities. More detailed descriptions of each activity can be found in the appendices. Also found in this chapter are descriptions of the analytical program implemented for this RFI and the data management and validation procedures.

Ecological Study

An onsite ecological study was conducted by a CH2M HILL ecologist to define the general environmental setting of the base, characterize the ecology in the vicinity of each site, and identify environmental receptors most likely to be exposed to site contaminants. Evidence of stress (e.g., stressed or dead vegetation, bare soil, and erosion), if present, was also noted. Many species of wildlife, birds in particular, were not present during the onsite ecology study because it was conducted in the late fall and early winter season when many species were hibernating or had migrated to their wintering grounds. In addition, identifying plant species observed onsite was difficult because of the lack of foliage or other identifying characteristics. Appendix A includes a detailed description of the ecological study and the ecological assessment of the contaminant data. Appendix A also contains lists of plant and wildlife species likely to occur at Oceana or in the Virginia Beach area at other times of the year.

Table 3-1
SUMMARY OF RFI FIELD ACTIVITIES

	Site 1 West Woods	Site 2B Line Shack 130-31	Site 2C Line Shack 400	Site 2D Line Shack 125	Site 2E Line Shack 109	Site 11 Firefighting Rings	Site 15 Abandoned Tank Farm	Site 16 Pesticide Storage Areas	Site 18 Hazardous Waste Storage Areas
Monitoring Wells:									
Shallow (~20′)	3	5	4	--	--	2	--	--	--
Deep (~50′)	3	2	2	--	--	--	--	--	--
In situ Hydraulic Conductivity Test	6	--	--	--	--	--	--	--	--
Sample Collection:									
Hydraulic Probe	--	20	13	--	--	--	12	--	--
Soil Borings	15	4	3	--	--	--	--	--	--
Groundwater	9	18	15	3	3	4	--	--	--
Surface Water	4	4	--	--	--	--	--	--	--
Sediment	4	3	--	--	--	--	--	--	--
Soil	2	3	2	--	4	5	--	8	2

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Table 3-1
SUMMARY OF RFI FIELD ACTIVITIES

	Site 19 Waste Oil Storage Area Bldg. 541	Site 20 Waste Oil Storage Area Bldg. 543	Site 21 Transformer Storage Yard	Site 22 Construction Debris Landfill	Site 23 Bowser Bldg. 830	Site 24 Bowser Bldg. 840	Site 25 Inert Landfill	Site 26 Firefighting Training Area
Monitoring Wells:								
Shallow (~20')	--	--	--	4	--	--	--	--
Deep (~50')	--	--	--	--	--	--	--	--
In situ Hydraulic Conductivity Test	--	--	--	--	--	--	--	--
Sample Collection:								
Hydraulic Probe	--	--	--	--	--	--	--	--
Soil Borings	--	--	--	--	--	--	--	--
Groundwater	--	--	--	4	--	--	--	--
Surface Water	--	--	--	2	--	--	2	--
Sediment	--	--	--	2	--	--	3	--
Soil	1	4	10	--	2	2	--	5

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Hydraulic Probe Sampling

An *in situ* groundwater sampling program was conducted using hydraulic probe at Sites 2B, 2C, and 15. The samples typically were collected from a depth of 9 to 12 feet at Sites 2B and 2C and from 6 to 9 feet at Site 15. After the groundwater samples were collected, they were analyzed on the site within hours by using a laboratory-grade gas chromatograph equipped with two high-sensitivity detectors, thus allowing for rapid site characterization.

Strict field sampling and field laboratory quality assurance/quality control procedures were followed to ensure the integrity of the analytical data and to comply with Navy and EPA requirements. The hydraulic probe sampling and onsite analysis was performed by Envirosurv, Inc. of Fairfax, Virginia. This work is described in detail in Appendix B.

Drilling and Monitoring Well Installation

The drilling and installation of 25 monitoring wells at Oceana NAS as part of the RFI occurred from December 2, 1992, to January 13, 1993. Hardin-Huber, Incorporated of Baltimore, Maryland, performed the drilling under the supervision of CH2M HILL. Eighteen wells were installed to shallow depths of approximately 20 to 24 feet. The remaining seven monitoring wells were installed to deeper depths of approximately 51 to 65 feet. For additional details on drilling and monitoring well installation, refer to Appendix C.

Environmental Sampling

CH2M HILL personnel collected a wide variety of samples at various sites as part of the RFI. Groundwater samples were collected from 55 monitoring wells at 7 sites. Surface water and sediment samples were collected from drainage ditches at Sites 1, 2B, and 22 and a pond at Site 25. Soil samples were collected at numerous locations across the base using a stainless-steel hand auger, trowel, and mixing bowl. Specific procedures regarding sample collection are discussed in greater detail in Appendix D.

A detailed quality assurance program was implemented for the RFI sampling round to ensure the integrity of all environmental samples collected. Equipment blanks were collected regularly to assess the potential of cross-contamination. Samples were collected in jars and containers provided by the laboratory, packed into coolers with vermiculite, and kept on ice throughout the daily sample collection and shipment. The decontamination of sampling equipment included a seven-step process to eliminate any potential for cross-contamination. A detailed discussion of the quality assurance sampling, sample handling procedures, and decontamination procedures is found in Appendix D.

In Situ Hydraulic Conductivity Tests

The *in situ* hydraulic conductivity of the aquifer at six wells at Site 1 was measured during the RFI. Pressure transducers and an electric data logger were used to record changing water levels during the testing. This work is described in Appendix E.

Other Field Activities

As part of the RFI's field investigation, additional field activities were necessary, including surveying, drum stockpiling, and groundwater collection.

Baldwin and Gregg of Norfolk, Virginia, surveyed the elevations of all new monitoring wells. Other elevations surveyed were the drainage ditches at Sites 1 and 2B, soil borings, and pre-existing wells.

Potentially contaminated groundwater also was collected from Sites 1, 2B, and 2C during the RFI. At most monitoring wells, potentially hazardous groundwater was collected in a large tanker truck provided by C&M Oil of Chesapeake, Virginia. According to non-detect TCLP laboratory results, the groundwater was treated and disposed off the site.

Analytical Program

CH2M HILL implemented a comprehensive analytical program as part of this RFI. Groundwater, soil, sediment and surface water samples comprise the list of environmental media analyzed. Samples from some or all of these media were analyzed at the 17 sites. The samples were packaged in their respective bottles or jars and submitted to the CH2M HILL laboratory in Montgomery, Alabama. Tables 3-2 through 3-4 summarize the sampling and analysis programs for groundwater, soil, sediment, and surface water.

Table 3-5 is a complete list of individual constituents included in each analytical method. The site-specific tables in Chapter 4 list only the detected compounds. Table 3-5 serves as a reference list for undetected constituents.

The RFI analytical program included quality control sampling. Quality control samples were analyzed to provide a measure of cross-contamination sources (field blanks), decontamination efficiency (equipment blanks) and other errors that can be introduced from sources other than the sample (i.e., shipment). Duplicate samples and matrix spike/matrix spike duplicate (MS/MSD) samples are useful in providing a measure of the internal consistency of the sample, and an estimate of variance and bias. Quality control sampling frequencies included one duplicate per 10 samples and one MS/MSD per 20 samples. Other blanks included one equipment blank per day, one field blank per sampling event, and one trip blank for every day that volatile samples were shipped.

Table 3-2
SUMMARY OF GROUNDWATER SAMPLING AND ANALYSIS PROGRAM
NAVAL AIR STATION, OCEANA
RCRA FACILITY INVESTIGATION

Parameters	Analytical Method[a]	Number of Samples to Be Collected							
		Site 1* (9)	Site 2B[d] (18)	Site 2C[d] (15)	Site 2D (3)	Site 2E (3)	Site 11 (4)	Site 15[d]	Site 22 (4)
Volatiles[c]	SW-8240	9			3	3	4		3
Semi-Volatiles	SW-8270		1	1	1	1			3
Base-Neutral Extractable Organics	SW-8270						1		
Pesticides and PCBs	SW-8080								3
Chlorinated Volatiles[c]	SW-8010		20	17					
Aromatic Volatiles	SW-8020							1	
Total Metals	SW-6010/7000	9				3	4		3
Disolved Metals	SW-6010/7000	8				3	4		3
Appendix IX[b] w/Total Metals		1							1
Appendix IX Dissolved Metals		1							1
Polynuclear Aromatics	SW-8100	9			2	2	3	1	
PCBs	SW-8080	9							
Dioxin	SW-8280	1							
Total Lead	SW-7421							1	
Dissolved Lead	SW-7421							1	

Notes:
( )The number of monitoring wells sampled at each site.
[a]Analytical methods as per *Test Methods for Evaluating Solid Waste*, 3rd Edition, Dec. 1986.
[b]Analytical methods for Appendix IX parameters are given in Appendix A.
[c]A detection limit of 2 $\mu g/l$ or less was required for vinyl chloride.
[d]See description of soil gas and in-situ groundwater sampling at Site 15 in Chapter 4. In-situ groundwater samples were also collected at Site 2B and 2C. This table includes standard laboratory analyses only, not mobile lab analyses.
*Site 1 totals include 9 wells and 1 free product sample. The floating free product sample was not analyzed for dissolved metals. The dense free product was analyzed for VOCs and PAHs.

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Table 3-3
SUMMARY OF SOIL SAMPLING AND ANALYSIS PROGRAM
NAVAL AIR STATION, OCEANA
RCRA FACILITY INVESTIGATION

Parameters	Analytical Method[a]	Number of Samples to Be Collected												
		Site 1	Site 2B	Site 2C	Site 2E	Site 11	Site 16[d]	Site 18	Site 19	Site 20	Site 21	Site 23	Site 24	Site 26
Volatiles	SW-8240	9			6	5			1	4		2	2	5
TPH	SM-418.1[c]				6	5			1	4	2	2	2	5
Appendix IX Chlorinated Pesticides, Organo. Pesticides	SW-8080 SW-8140						8							
Appendix IX Herbicides	SW-8150						8							
Lead	SW-7421						4		1	4				
Metals	SW-6010/7000	9			6	5						2	2	5
Ignitability														
Appendix IX[b]		2						2						5
Polynuclear Aromatics	SW-8100	9			5	5			1	4		2	2	
PCBs	SW-8080	9									10			5
Chlorinated VOCs	SW-8010		14	8										
Arsenic	SW-7060						4							
Copper	SW-7211						4							
Semivolatiles	SW-8270				1									

Notes:
[a]Analytical methods as per *Test Methods for Evaluating Solid Waste*, 3rd Edition, Dec. 1986.
[b]Analytical methods for Appendix IX parameters are given in Appendix A.
[c]Analytical method as per *Standard Method for Analysis of Water and Wastewater*.
[d]Numbers include samples from golf course pesticide shop.

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Table 3-4
SUMMARY OF SURFACE WATER AND SEDIMENT SAMPLING AND ANALYSIS PROGRAM
NAVAL AIR STATION, OCEANA
RCRA FACILITY INVESTIGATION

Parameters	Analytical Method[a]	Number of Samples to Be Collected					
		SWMU 1		SWMU 2B		SWMU 25	
		Surface Water	Sediment	Surface Water	Sediment	Surface Water	Sediment
Volatiles[c]	SW-8240	4	4			1	2
Semi-Volatiles	SW-8270					1	2
Pesticides and PCBs	SW-8080					1	2
Total Metals	SW-6010/7000	4	4			1	2
Dioxin	SW-8280	1	1				
Appendix IX[b]						1	1
Polynuclear Aromatics	SW-8100	4	4	4	3		
PCBs	SW-8080	4	4				
Chlorinated VOCs[c]	SW-8010			4	3		

Notes:
[a]Analytical methods as per *Test Methods for Evaluating Solid Waste*, 3rd Edition, Dec. 1986.
[b]Analytical methods for Appendix IX parameters are given in Appendix A.
[c]A detection limit of 2 ug/l or less was required for vinyl chloride in water.

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Table 3-5
CHEMICAL PARAMETERS FOR LABORATORY ANALYSIS

Volatile Organic Compounds (SW-8240)

Acetone	1,2-Dichloroethylene (total)
Acrolein	1,2-Dichloropropane
Acrylonitrile	cis-1,3-Dichloropropene
Benzene	trans-1,3-Dichloropropene
Bromodichloromethane	trans-1,4-Dichloro-2-butene
Bromoform	Ethyl methacrylate
Bromomethane	Ethylbenzene
2-Butanone (methyl ethyl ketone)	2-Hexanone
Carbon disulfide	Idomethane
Carbon tetrachloride	4-Methyl-2-pentanone
Chlorobenzene	Methylene chloride
Chloroethane	Styrene
2-Chloroethyl vinyl ether	1,1,2,2-Tetrachloroethane
Chloroform	Tetrachloroethene
Chloromethane	1,1,1-Trichloroethane
Dibromochloromethane	1,1,2-Trichloroethane
Dibromomethane	Trichloroethene
1,2-Dichlorobenzene	Trichlorofluoromethane
1,3-Dichlorobenzene	1,2,3-Trichloropropane
1,4-Dichlorobenzene	Toluene
1,1-Dichloroethane	Vinyl acetate
1,2-Dichloroethane	Vinyl chloride
1,1-Dichloroethylene	Xylene (total)

Table 3-5
CHEMICAL PARAMETERS FOR LABORATORY ANALYSIS

Semi-Volatile Organic Compounds (SW-8270)

Acenaphthene	Diphenylamine
Acenaphthylene	bis(2-Ethylhexyl)phthalate
Acetophenone	Ethylmethane sulfonate
4-Aminobiphenyl	Fluoranthene
Aniline	Fluorene
Anthracene	Hexachlorobenzene
Benzidine	Hexachlorobutadiene
Benzo(a)anthracene	Hexachlorocyclopentadiene
Benzo(a)pyrene	Hexachloroethane
Benzo(b)fluoranthene	Indeno(1,2,3-cd)pyrene
Benzo(g,h,i)perylene	Isophorone
Benzo(k)fluoranthene	2-Methylnaphthalene
Benzoic Acid	3-Methyl cholanthrene
Benzyl alcohol	2-Methyl-4,6-dinitrophenol
4-Bromophenyl phenyl ether	Methylmethane sulfonate
Butyl benzyl phthalate	2-Methyl phenol
4-Chloroaniline	4-Methyl phenol
bis(2-Chloroethoxy) methane	1-Naphthylamine
bis(2-Chloroethyl) ether	2-Naphthylamine
bis(2-Chloroisopropyl) ether	2-Nitroaniline
4-Chloro-3 methyl phenol	3-Nitroaniline
1-Chloronaphthalene	4-Nitroaniline
2-Chloronaphthalene	2-Nitrophenol
2-Chlorophenol	4-Nitrophenol
4-Chlorophenyl phenyl ether	n-Nitroso-di-n-butylamine
Chrysene	N-Nitrosodi-n-propylamine
Dibenzo(a,h)anthracene	n-Nitrosodimethylamine
Dibenzofuran	N-Nitrosodiphenylamine
Dibutyl phthalate	n-Nitrosopiperidine
3,3'-Dichlorobenzidine	Pentachlorobenzene
1,2-Dichlorobenzene	Pentachloronitrobenzene
1,3-Dichlorobenzene	Pentachlorophenol
1,4-Dichlorobenzene	Phenacetin
2,4-Dichlorophenol	Phenanthrene
2,6-Dichlorophenol	Phenol
Diethyl phthalate	Phenyl-tert-butylamine
p-Dimethylamino(azo)benzene	2-Picoline
7,12-Dimethyl(a)anthracene	Pronamide
2,4-Dimethylphenol	Pyrene
Dimethyl phthalate	1,2,4,5-Tetrachlorobenzene
Di-n-octyl phthalate	2,3,4,6-Tetrachlorophenol
2,4-Dinitrophenol	1,2,4-Trichlorobenzene
2,4-Dinitrotoluene	2,4,5-Trichlorophenol
2,6-Dinitrotoluene	2,4,6-Trichlorophenol
1,2-Diphenylhydrazine	

Tab...
CHEMICAL PARAMETERS FOR LABORATORY ANALYSIS

Pesticides and PCBs (SW-8080)	Metals (SW-6010/7000)
Alpha-BHC	Aluminum
Beta-BHC	Antimony
Delta-BHC	Arsenic
Gamma-BHC (lindane)	Barium
Heptachlor	Beryllium
Aldrin	Cadmium
Heptachlor epoxide	Calcium
Endosulfan I	Chromium
Dieldrin	Cobalt
4,4'-DDE	Copper
Endrin	Cyanide
Endosulfan II	Iron
4,4'-DDD	Lead
Endosulfan sulfate	Magnesium
4,4-DDT	Manganese
Methoxychlor	Mercury
Endrin aldehyde	Nickel
Chlordane	Potassium
Toxaphene	Selenium
PCB-1016	Silver
PCB-1221	Sodium
PCB-1232	Sulfide
PCB-1242	Thallium
PCB-1248	Tin
PCB-1254	Vanadium
PCB-1260	Zinc

Chlorinated Volatiles (SW-8010)

Bromodichloromethane	1,2-Dichloroethane
Bromoform	1,1-Dichloroethylene
Bromomethane	cis-1,2-Dichloroethlyene
Carbon tetrachloride	trans-1,2-Dichloroethylene
Chlorobenzene	1,2-Dichloropropane
Chloroethane	cis-1,3-Dichloropropene
2-Chloroethylvinyl ether	trans-1,3-Dichloropropene
Chloroform	Methylene chloride
Chloromethane	Tetrachloroethene
Dibromochloromethane	1,1,2,2-Tetrachloroethane
Dichlorodifluoromethane	1,1,1-Trichloroethane
1,2-Dichlorobenzene	1,1,2-Trichloroethane
1,3-Dichlorobenzene	Trichloroethene
1,4-Dichlorobenzene	Trichlorofluoromethane
1,1-Dichloroethane	Vinyl chloride

Table 3-5
CHEMICAL PARAMETERS FOR LABORATORY ANALYSIS

Aromatic Volatiles (SW-8020)	
Ethylbenzene	1,2-Dichlorobenzene
m- and p-Xylene	1,3-Dichlorobenzene
o-Xylene	1,4-Dichlorobenzene
Xylenes (total)	Benzene
Toluene	Chlorobenzene
	Methyl tert butyl ether
Polynuclear Aromatic Hydrocarbons (SW-8100)	
Acenaphthene	Dibenzo (a,h) anthracene
Acenaphthylene	Fluoranthene
Anthracene	Fluorene
Benzo (a) anthracene	Indeno (1,2,3-cd) pyrene
Benzo (a) pyrene	1-Methylnaphthalene
Benzo (b) fluoranthene	2-Methylnaphthalene
Benzo (g,h,i) perylene	Naphthalene
Benzo (k) fluoranthene	Phenanthrene
Chrysene	Pyrene
Dioxin	
2,3,7,8 Tetrachlorinated-dibenzo dioxins	
Organophosphorus Pesticide Compounds (SW-8140)	
Azinophos methyl (Guthion)	Merphos
Bolstar (Sulprofos)	Mevinphos (Phosdrin)
Chlorpyrifos	Naled
Coumaphos	Parathion methyl
Demeton O&S	Phorate
Diazinon	Ronnel
Dichlorvos	Stirofos (Rabon)
Disulfoton	Tokuthion (Prothiofos)
Ethoprop	Trichlornate
Fensulfothion Fenthion	
Herbicide Compounds (SW-8150)	
2,4-D	2,4-DP (Dichloroprop)
2,4-DB	MCPA
Dalapon	MCPP
Dicamba	Silvex (2,4,5-TP)
Dinoseb	2,4,5-T

Table 3-5
CHEMICAL PARAMETERS FOR LABORATORY ANALYSIS

Appendix IX. Volatile Compounds

Acetone	1,2-Dichloroethylene (total)
Acetonitrile	1,2-Dichloropropane
Acrolein	cis-1,3-Dichloropropene
Acrylonitrile	trans-1,3-Dichloropropene
Benzene	1,4-Dioxane
Bromodichloromethane	Ethylbenzene
Bromoform	Ethyl methacrylate
Bromomethane	2-Hexanine
2-Butanone	Iodomethane
Carbon Tetrachloride	Isobutyl alcohol
Carbon disulfide	Methacrylonitrile
Chlorobenzene	Methylene chloride
Chloroethane	Methyl methacrylate
2-Chloroethylvinylether	4-Methyl-2-pentanone
Chloroform	Pentachloroethane
Chloromethane	1,1,1,2-Tetrachloroethane
3-Chloropropene	1,1,2,2-Tetrachloroethane
Chloroprene	1,1,1-Trichloroethane
Dibromochloromethane	1,1,2-Trichloroethane
1,2-Dibromo-3-chloropropane	1,2,3-Trichloropropane
Dibromomethane	Propionitrile
1,2-Dibromoethane	Styrene
1,2-Dichlorobenzene	Tetrachloroethene
1,3-Dichlorobenzene	Toluene
1,4-Dichlorobenzene	Trichloroethene
trans-1,4-Dichloro-2-butene	Trichlorofluoromethane
Dichlorodifluoromethane	Vinyl Acetate
1,1-Dichloroethane	Vinyl chloride
1,2-Dichloroethane	Xylene (total)
1,1-Dichloroethylene	

Table 3-5
CHEMICAL PARAMETERS FOR LABORATORY ANALYSIS

Appendix IX. Organophosphorus Pesticide Compounds
Dimethoate
Disulfoton
Ethyl Parathion
Famphur
Methyl Parathion
Phorate
Sulfotepp
Thionazin
Triethylphosphorothioate
Appendix IX. Herbicide Compounds
2,4-D
Dinoseb
Silvex
2,4,5-T
Appendix IX. Dioxins/Furans
Hexachlorinated-dibenzo dioxins
Pentachlorinated-dibenzo dioxins
2,3,7,8 Tetrachlorinated-dibenzo dioxins
Tetrachlorinated-dibenzo dioxins
Hexachlorinated-dibenzo furans
Pentachlorinated-dibenzo furans
Tetrachlorinated-dibenzo furans

Appendix IX. Semivolatile Compounds

Acenaphthene
Acenaphthylene
2-Acetamidofluorene
Acetophenone
4-Aminobiphenyl
Aniline
Anthracene
Aramite
Benzidine
Benzo(a)anthracene
Benzo(a)pyrene
Benzo(b)fluoranthene
Benzo(g,h,i)perylene
Benzo(k)fluoranthene
Benzoic acid
Benzyl alcohol
4-Bromophenyl-phenylether
Butylbenzylphthalate
4-Chloroaniline
bis(2-Chloroethoxy)methane
bis(2-Chloroethyl)ether
bis(2-Chloroisopropyl)ether
4-Chloro-3-methylphenol
2-Chloronaphthalene
2-Chlorophenol
4-Chlorophenyl-phenylether
Chrysene
Dibenz(a,h)anthracene
Dibenzofuran
1,2-Dichlorobenzene
1,3-Dichlorobenzene
1,4-Dichlorobenzene
3,3'-Dichlorobenzidine
2,4-Dichlorophenol
2,6-Dichlorophenol
Diethylphthalate
p-Dimethylaminoazobenzene
7,12-Dimethylbenz(a)anthrac
3,3'-Dimethylbenzidine
2,4-Dimethylphenol
Dimethylphthalate
Di-n-butylphthalate
1,3-Dinitrobenzene
4,6-Dinitro-2-methylphenol
2,4-Dinitrophenol
2,4-Dinitrotoluene
2,6-Dinitrotoluene
Di-n-octyl-phthalate
Diphenylamine
1,2-Diphenylhydrazine
bis(2-Ethylhexyl)phthalate
Ethyl methanesulfonate
Fluoranthene
Fluorene
Hexachlorobenzene
Hexachlorobutadiene
Hexachlorocyclopentadiene
Hexachloroethane
Hexachlorophene
Hexachloropropene
Indeno(1,2,3-cd)pyrene
Isophorone
Isosafrole
Methapyrilene
3-Methylcholanthrene
Methyl methanesulfonate
2-Methylnaphthalene
2-Methylphenol
3-Methylphenol
4-Methylphenol
Naphthalene
1-Naphthylamine
2-Naphthylamine
1,4-Napthoquinone
2-Nitroaniline
3-Nitroaniline
4-Nitroaniline
Nitrobenzene
5-Nitro-o-toluidine
2-Nitrophenol
4-Nitrophenol
4-Nitroquinoline-1-oxide
N-Nitrosodiethylamine
N-Nitrosodimethylamine
N-Nitroso-Di-n-butylamine
N-Nitroso-Di-n-propylamine
N-Nitrosodiphenylamine
N-Nitrosomethylethylamine
N-Nitrosomorpholine
N-Nitrosopiperidine
N-Nitrosopyrrolidine
Pentachlorobenzene
Pentachloronitrobenzene
Pentachlorophenol
Phenacetin
Phenathrene
Phenol
p-Phenylenediamine
Phenyl-tert-butylamine
2-Picoline
Pronamide
Pyrene
Pyridine
Safrole
1,2,4,5-Tetrachlorobenzene
2,3,4,6-Tetrachlorophenol
o-Toluidine
1,2,4-Trichlorobenzene
2,4,5-Trichlorophenol
2,4,6-Trichlorophenol
1,3,5-Trinitrobenzene

Table 3-5
CHEMICAL PARAMETERS FOR LABORATORY ANALYSIS

Appendix IX. Pesticide/PCB Compounds

Aldrin	4,4′ DDT
Aroclor-1221	Diallate
Aroclor-1016	Dieldrin
Aroclor-1248	Endosulfan I
Aroclor-1242	Endosulfan II
Aroclor-1254	Endosulfan Sulfate
Aroclor-1232	Endrin
Aroclor-1260	Endrin Aldehye
alpha-BHC	Endrin Ketone
beta-BHC	Heptachlor
delta-BHC	Heptachlor Epoxide
gamma-BHC (Lindane)	Isodrin
Chlordane	Kepone
Chlorobenzilate	Methoxychlor
4,4′ DDD	Toxaphene
4,4′ DDE	

Appendix IX. Metals

Antimony	Mercury
Arsenic	Nickel
Barium	Selenium
Beryllium	Silver
Cadmium	Sulfide
Chromium	Thallium
Cobalt	Tin
Copper	Vanadium
Cyanide	Zinc
Lead	

Data Management and Validation

The RFI data management program reduced extensive Level C laboratory packages to tabulated results of detected constituents. The tables included in Chapter 4 present only the constituents detected during the RFI or previous investigations. The Chapter 4 data tables present all historical sampling results for the 17 sites.

Data validation entails a review of the quality control (QC) data and the raw sample data to verify that the analytical laboratory has operated within the required control limits, the analytical results are correctly transcribed from the instrument readouts, and which, if any, natural samples are related to any out-of-control laboratory QC samples. The objective of the data validation is to identify any qualitative, unreliable, or invalid laboratory measurements.

The data validation process consists of reviewing laboratory holding times, instrument tuning and calibration, blanks, field duplicates, surrogate recovery, matrix spike/matrix spike duplicates, internal standards performance, system performance, and reported detection limits.

CH2M HILL validators validated the analytical data by using EPA protocols, (*Laboratory Data Validation Functional Guidelines for Evaluating Organics and Inorganics Analyses* and *U.S. EPA Region III Functional Guideline Modifications*), and Navy data validation procedures for Level C data packages specified in *Sampling and Analysis Quality Assurance Requirements for the Navy Installation and Restoration Program*. The Oceana RFI Data Validation Report is found in Appendix G.

WDCR702/042.51

Chapter 4
Individual Site Investigations

Introduction

This chapter presents background and RFI results for each of the 17 SWMUs investigated during the RFI. The 17 individual site sections are autonomous presentations of all elements of the RFI results and analysis for each site. The elements discussed in this section are:

- Site location and history
- Past investigations and RFI site activities
- Environmental setting
- Contamination and extent
- Health and environmental assessment
- Fate and transport
- Recommendations

The environmental setting section describes the topography, surface water resources, ecology, and geologic and hydrogeologic characteristics of the site. Within the ecology subsection, vegetation, wildlife, and wetlands observed during ecological studies of the individual sites are described.

Within the contamination and extent section, types of field sampling are described separately for Sites 1, 2B, 2C, 22, and other sites where a number of media were sampled. Tables of all historical data from previous investigations at locations resampled during the RFI are included with the Chapter 4 text. Only detected constituents are listed. In the metals tables, the "<" symbol is used for metals that were not detected. The number indicates the instrument detection limit. The emphasis in the discussion is on the RFI results; however, some comparisons to previous results is included where appropriate, especially when confirmation was an explicit goal of the RFI sampling.

Chapter 4 includes site-specific human HEAs. Some details of the HEA are described in more detail in Appendix A. The purpose of the HEA section is to provide guidance as to whether a CMS should be performed at the site. The assessment is performed primarily by comparing criteria and standards used in the RCRA corrective action guidance and other sources to measured concentrations in the environmental media. However, the assessment also incorporates guidelines and approximations from the literature on ecological effects. The comparisons are not meant to evaluate risk definitely, which would require a more detailed site-specific risk assessment, rather the comparisons are used as tools and markers for contamination levels that may be of concern.

The HEA comparison tables in Chapter 4 are a composite of established and proposed standards, criteria, and background concentrations. For example, maximum contaminant levels (MCL) are established standards for drinking water supplies. The pertinence of this standard is related to the potential exposure of people and animals to groundwater. Health-based criteria for carcinogens or for systemic toxicants are regulatory guidelines that also are based on certain ingestion and exposure assumptions that may not apply to potential human or ecological receptors at each site. The proposed RCRA action limit and the Virginia groundwater guidelines also are established or proposed guidelines that may or may not apply to the given site situation. At sites where no additional actions are recommended, risk-based concentrations (RBCs) calculated by toxicologists at EPA Region III were used for comparison (EPA, 1993). However, as stated by the author of the RBC table, these concentrations should be used for screening rather than as criteria or interim guidance.

The primary criteria used to assess the potential threat to human health are MCLs and proposed RCRA action levels. Both these standards are based on conservative assumptions of body weight, ingestion and inhalation rates, and the length of exposure. For example most MCLs are based on a maximum 1×10^{-6} cancer rate for a residential population ingesting a given soil or water for more than 25 years. By contrast, several site factors decrease the exposure of personnel at NAS Oceana compared to the population and situation assumed in preparing human health criteria and guidelines. These are:

1. **Water Supply**. The station is served by water from the City of Norfolk Department of Utilities. No groundwater is used within the boundary of the station for any purpose.

2. **Longevity**. The population consists primarily of enlisted men and women present at Oceana for 2 to 3 years. Other career military personnel generally are not stationed at Oceana for more than a few years.

3. **Adult Population**. The people living and working on the station are almost exclusively adults.

4. **Limited Access**. The station is not open to the general public. Access is controlled at all entrances and access to flightline areas, where most of the RFI sites are located, is strictly controlled by guards and a security fence.

5. **Industrial Use**. The station is used to service, maintain, and operate aircraft and as such has a primarily industrial function.

6. **Future of NAS Oceana**. NAS Oceana is one of 2 or 3 master jet bases in the country and is the primary naval air station on the east coast. Under the base realignment and closure program, other operations from closed facilities are being consolidated at NAS Oceana. Therefore, site controls most likely will continue and groundwater will not be used in the future.

These factors were not considered in screening concentrations against numerical criteria but were considered in recommending no further action at a site. At sites where additional actions are recommended no detailed risk analysis is provided because a risk analysis would not alter the decision to proceed with the investigation or a CMS.

The ecological criteria listed in the RBC table are a composite of guidelines and comparisons to background levels. Few ecological criteria, either established or proposed, exist for organics and inorganics. Because ecological criteria are in the early stages of development, rough approximations are made to give some sense of potential ecological effects of the detected constituents. For example, because no ecological criteria exist for terrestrial organisms, human health criteria for ingestion of water and fish are used. These rough approximations do not demonstrate that ecological exposures are a threat; they are a screening methodology to give a general sense of the magnitude of detected constituents. A presentation of the methodology of the environmental assessment (EA) is included in Appendix A. The appendix also describes exposure studies for constituents identified as potential ecological chemicals of concern using the guidelines and approximations described in Appendix A.

Site 1—West Woods Oil Disposal Pit

Site Location and History

The West Woods Oil Disposal Pit is in the northwest part of NAS Oceana, approximately 1,000 feet west of abandoned Runway 9 and the fire-fighting training area (see Figure 1-1). According to the IAS, the site was originally an open pit in which an estimated 110,000 gallons of waste oil, fuels (such as JP-5, JP-3, and AVGAS), PD 680, various chlorinated and aromatic hydrocarbons (trichlorotrifluoromethane, benzene, toluene, and naphtha), aircraft-maintenance chemicals, paints, paint thinners and strippers, and agitine were disposed of from the mid-1950s to the late 1960s (RGH, 1984). Drilling at this site also has shown that metal, concrete, and other debris were disposed of in the pit or were included in the fill material. On the basis of a 1958 aerial photograph of the site, the pit appears to have been approximately 50 to 100 feet in diameter.

In the late 1960s, the pit flooded and its contents are believed to have washed into the main drainage ditch, 100 feet west of the oil disposal pit. As a result, waste disposal ceased and the pit was filled with soil (RGH, 1984). The NAS boundary is approximately 1,000 to 2,000 feet west or northwest of the oil pit. The NAS Oceana Environmental Division monitors the ditch downstream of Site 1 as part of the station's Virginia Pollution Discharge Elimination system (VPDES) monitoring program.

The IAS describes another ditch, which was approximately 1,000 feet long, that connected Runway 9 to the oil disposal pit; however, this ditch was not visible in 1971 air photos and no evidence of the ditch was found in a 1984 field check or in later investigations. This ditch has not been located in subsequent investigations and no contamination associated with it has been identified.

Past Investigations and RFI Activities

Site 1 has been investigated on three previous occasions. The IAS conducted in 1984 identified this site and inventoried the types of waste liquids disposed in the pit. In 1986, CH2M HILL conducted a Phase I verification study, which was followed by the Interim RFI in 1991. These two investigations showed that the groundwater is contaminated locally with total petroleum hydrocarbons (TPH), volatile organic compounds (VOCs), and polychlorinated biphenols (PCBs). Sediment samples taken from the main drainage ditch to the west of the former West Woods Oil Pit contained petroleum constituents.

The purpose of the RFI field investigation was to determine the vertical and the lateral extent of groundwater contamination, and the hydraulic characteristics and flow regime of the shallow aquifer. This investigation also sought to characterize the type and extent of soil contamination near the pit, to confirm earlier data on the contamination of the surface water and sediment, and to determine if sediment and surface water contamination extends as far as the culvert 1,000 feet downstream from the area adjacent to the pit.

The field investigation included:

- Drilling 15 soil borings (1-SB1 through 1-SB15) and collecting a soil sample from 9 selected borings
- Installing 3 deep monitoring wells (1-MW7D, 1-MW8D, 1-MW9D) and 3 shallow monitoring wells (1-MW6, 1-MW7, and 1-MW8)
- Collecting two soil samples (1-SS1 and 1-SS2) between the pit and ditch
- Collecting four surface-water and sediment samples (1-SD1/1-SW1 through 1-SD4/1-SW4) from the main drainage ditch
- Collecting groundwater samples from new and existing monitoring wells (1-MW3, 1-MW4, and 1-MW5)
- Surveying for horizontal and vertical control
- Measurement of *in situ* hydraulic conductivity in 6 wells

The RFI sampling locations are shown in Figure 4-1-1. The Site 1 monitoring well network is summarized in Table 4-1-1.

Environmental Setting

Because of their proximity, the environmental settings of Sites 1 and 11 were studied as a unit. The total area of the combined sites is approximately 60 acres. Because the study area was large, the ecological assessment was conducted along several transects that traversed the area from east to west. The focus of the assessment in this area was on the large forested ecosystem between the abandoned Runway 9 and the radar station access road west of the main ditch. Figure 4-1-2 is an ecological map of Sites 1 and 11.

Except for a few drainage swales, the study area is relatively flat. The area slopes slightly and drains to the north or northwest. No evidence exists of recent disturbance in the forested area near SWMU 1. The fire-fighting training area has areas of highly disturbed soils and impervious surfaces. The area is surrounded by abandoned Runway 9, mowed grasses, and a disturbed area with old-field herbaceous and scrub-shrub species.

Ecology

Surface Water Resources. Surface drainage is directed toward east-west and north-south oriented ditches in which there is a permanent flow of water to the north. The main ditch is approximately 12 to 15 feet wide with steep side slopes about 5 feet high. The depth of the water in the ditch at the time of the survey was approximately 6 inches, but increased

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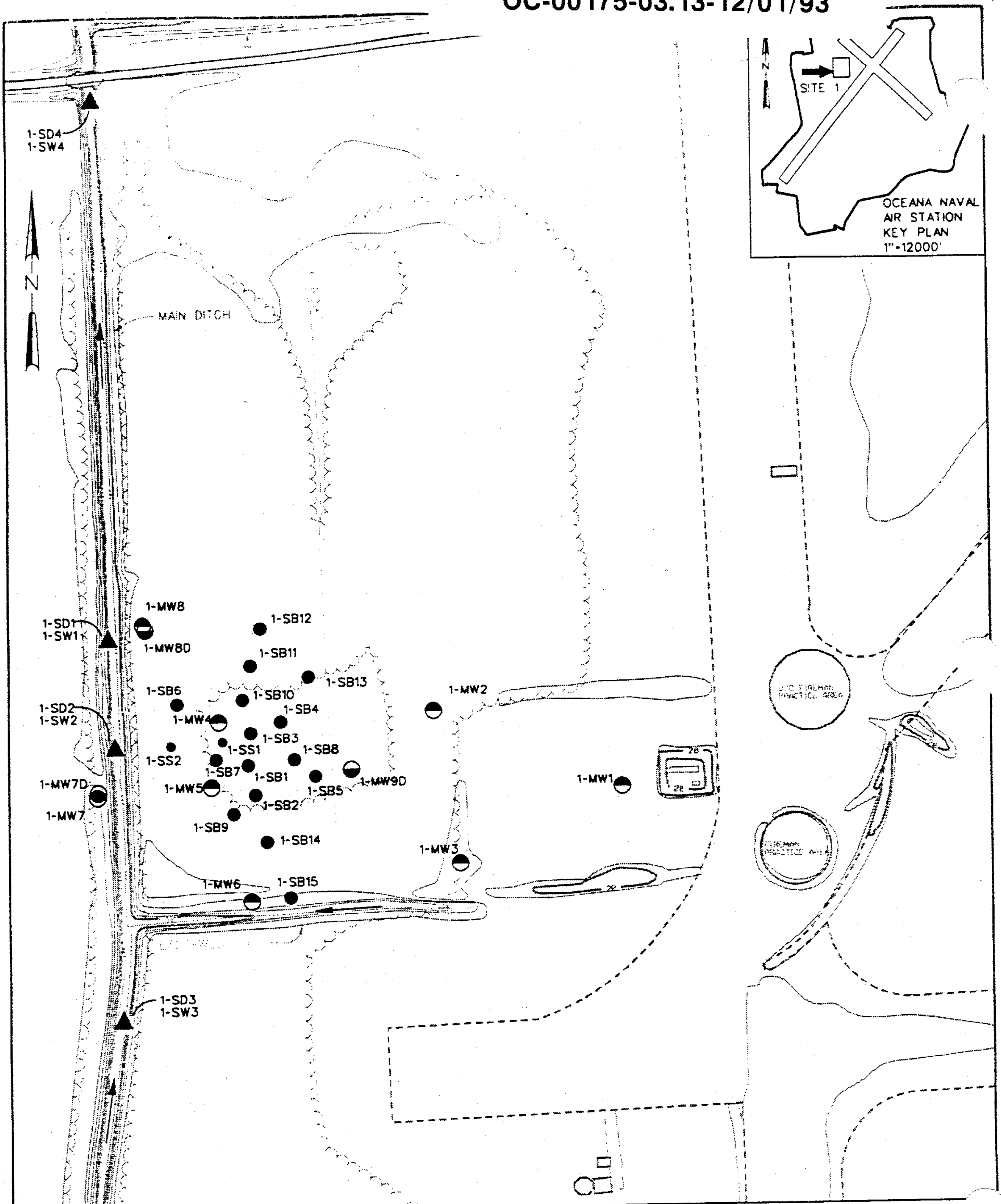

LEGEND
- SHALLOW MONITORING WELL
- DEEP MONITORING WELL
- SOIL SAMPLING LOCATION
- SOIL BORING LOCATION
- SEDIMENT AND SURFACE WATER SAMPLING LOCATION
- DIRECTION OF SURFACE WATER FLOW

0 100 200 300
SCALE IN FEET

Figure 4-1-1
RFI SAMPLING LOCATIONS AT SITE 1
JANUARY 1993

CH2M HILL

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Table 4-1-1 SITE 1 MONITORING WELL SUMMARY				
Well Number	Date Installed	Ground Elevation (feet above MSL)	Total Depth (feet)	Screened Interval (feet below ground surface)
01-MW1	04/02/86	15.3	20	10-20
01-MW2	04/02/86	17.1	19	9-19
01-MW3	04/01/86	17.2	19	9-19
01-MW4	06/27/90	16.9	18	8-18
01-MW5	06/27/90	16.7	18	8-18
01-MW6	01/08/93	15.4	20.5	5.5-20.5
01-MW7	12/22/92	17.2	22.5	7.5-22.5
01-MW7D	12/22/92	17.3	57.0	45-55
01-MW8	01/07/93	15.2	22.0	7-22
01-MW8D	01/06/93	15.4	55.0	45-55
01-MW9D	01/05/93	15.3	65.0	50-60

during the investigation in response to rain events. No submerged or floating aquatic vegetation was observed growing directly in the ditch. The sediment in the ditch is primarily sand and the water in the ditch appeared to be fairly clear.

A sheen was observed in some areas on both banks of the main ditch within a few inches of the water level of the base flow but was most abundant on the east bank. In addition, a sheen was observed on the surface of some of the slower moving portions of the flowing water adjacent to the east bank. When bottom sediments were disturbed, a petroleum-like odor was emitted from the areas of the ditch and a sheen was noticed. Within the water, a layer of reddish-brown clotted material was observed along much of the north-south ditch, both upstream and downstream of Site 1. The material is a flocculent made up of bacteria that thrive in iron-rich water. This flocculent is probably caused by iron precipitate in the water.

Wetlands. A large forested wetland community exists in the vicinity of Sites 1 and 11. Most of the forested area included in the field survey was upland or a mosaic of upland with small areas of forested wetlands occurring in patches. A small emergent wetland is between Sites 1 and 11. This circular wetland is approximately 100 feet in radius, with an average depth of about 6 inches. The water was clear and the sediments were typical of an emerging wetland. For instance, natural iron precipitate became more evident on the surface of the sediment near the outer edge of the wetland area. No visible signs of vegetative stress in the wetland were evident at the time of survey.

Vegetation. The vegetative community near Site 1 is dominated by forested species. The immediate area around the pit had more scrub-shrub and pioneer species, possibly because of previous disturbances. Figure 4-1-2 indicates the types of vegetative communities near Site 1 and Site 11. Species common to the forested area were most notably sweetgum, red maple, loblolly pine, southern red oak, wax myrtle, giant cane, and Japanese honeysuckle. Other species include chestnut oak, shagbark hickory, tulip poplar, eastern red cedar, greenbriar, poison ivy, and black gum. The emergent wetland area between Sites 1 and 11 is dominated by soft rush, wool grass, spike rush, and water purslane.

Wildlife. A variety of birds were observed during the assessment. Large numbers of yellow-rumped warblers were seen throughout the edges of the forested areas on the site. Other less commonly observed species included song sparrow, northern cardinal, blue jay, gray catbird, and downy woodpecker.

Of the mammal species known to occur in the area, only white-tail deer and red fox were observed. Signs, including tracks, scat, and den holes were used to identify other species in the area. These animals included raccoon, cottontail rabbit, and field mice. Other mammalian species known to occur in the area are listed in Appendix A.

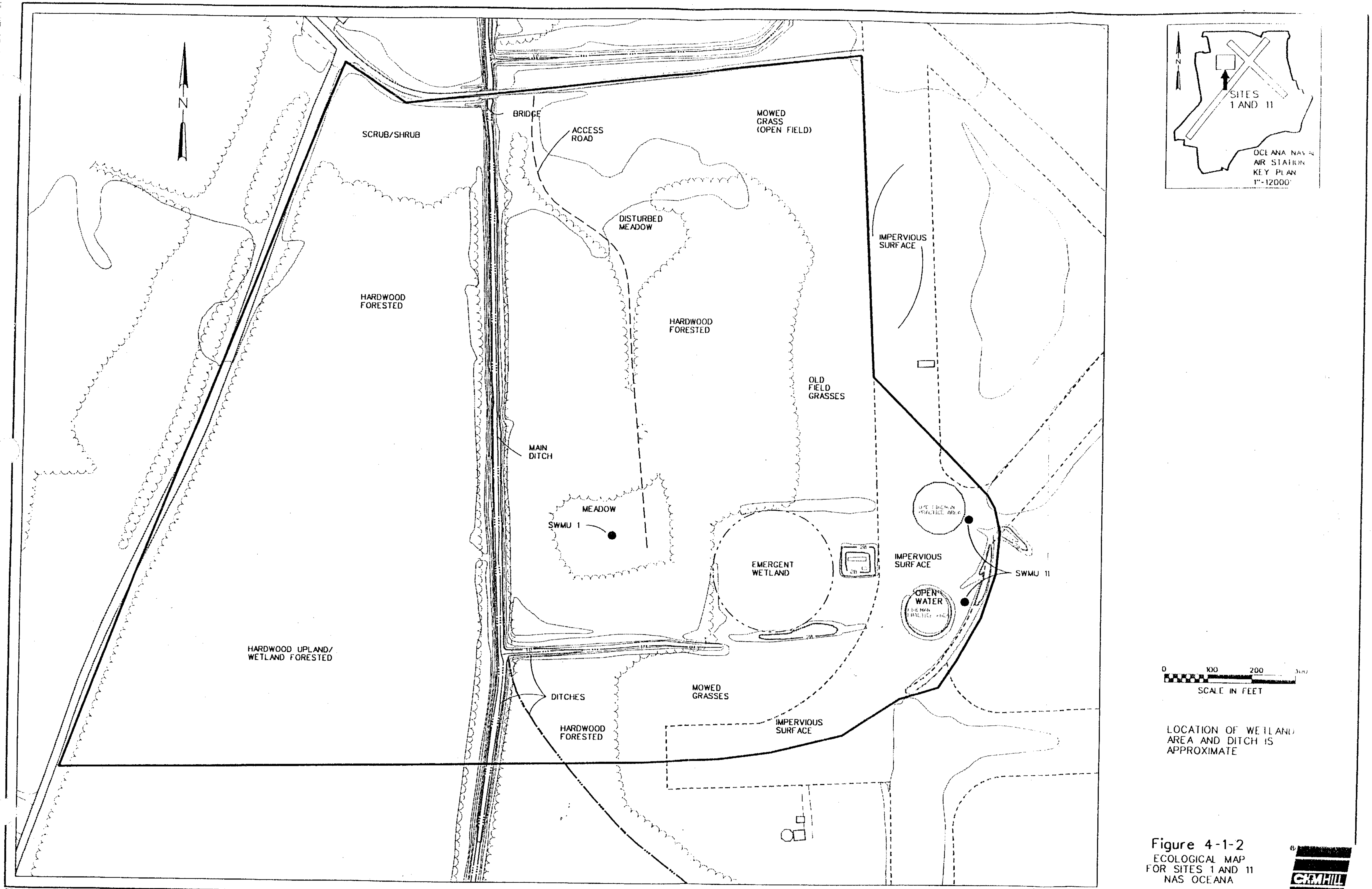

Figure 4-1-2
ECOLOGICAL MAP FOR SITES 1 AND 11
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Geologic and Hydrogeologic Characteristics

Site 1 is underlain by silt, sand, and silty sand in three distinct lithologic units that are generally consistent across the site. The uppermost unit is a brown silt or sandy silt that is 4.5 to 6 feet thick. Because of its lithology and the tendency of rainwater to pond for an extended period after heavy rains, this unit appears to have a low permeability.

Beneath the silt, an 11- to 13-foot-thick clean, fine to very coarse gray sand extends to a depth of 16 to 19 feet. Its sand fraction is generally fine to medium, but in some areas, it is silty in the top 1 to 2 feet and medium to very coarse in the bottom few feet. The depth to water is generally 4 to 8 feet. The water table is generally within the sand unit but rises into the silt locally during the wetter winter months. These two units are members of the Columbia Group sediments described in Chapter 2. The shallow monitoring wells are screened in the sand unit.

Underlying the clean gray sand is a third lithologic unit composed of very fine greenish-gray silty sand or sandy silt. The sand in this unit is extremely fine, only slightly coarser than a fine silt; as a result, silty sands and sandy silts in this unit are similar lithologically. This unit contains shell or shell hash starting at a depth of 23 to 28 feet and extending to final borehole depths of 57 to 65 feet. The presence of shells correlates with the Yorktown Formation described in Chapter 2. Three deep wells were screened in the Yorktown Formation. The tops of the 10-foot screen sections in these wells were placed 18 to 26 feet below the point where shells were initially observed in each boring. The first appearance of shells is assumed to correlate with the top of the Yorktown Formation.

The water levels measured at Site 1 on January 26, 1993, are listed in Table 4-1-2 and illustrated in Figure 4-1-3. Figure 4-1-3 also shows the estimated equipotential contour lines for the water table and the estimated elevation of the water surface in the main ditch. Deep-well water-level elevations are underlined in Figure 4-1-3 but are not contoured because data are insufficient.

The data show that shallow groundwater flows west from the oil pit area and discharges into the main drainage ditch. This is confirmed not only by the shallow groundwater elevations, but also by the vertical gradients near the ditch. The two paired wells near the ditch indicate that the vertical gradient is upward on both sides of the ditch. The head difference is 1.63 feet at the 1-MW8/1-MW8D well pair and 1.50 feet at 1-MW7/1-MW7D, which correspond to vertical gradients of approximately 0.046 foot/foot and 0.043 foot/foot, respectively. This upward gradient is consistent with the rising streamlines expected near a gaining stream or ditch.

The elevation of the sediment surface in the main ditch was surveyed as part of the RFI activities to confirm the relative elevations of groundwater and surface water. On the basis of a typical water-level depth of 6 inches, the estimated elevation of the water surface in the stream during surveying was 8.2 feet. This is 0.8 to 1.0 feet below the water table

Table 4-1-2
SITE 1 WATER-LEVEL DATA
January 1993

Well	Depth to Water (Feet Below Survey Datum)	Water-Level Elevation (Feet Above Mean Sea Level)
01-MW1	4.29	12.84
01-MW2	6.00	12.59
01-MW3	7.25	12.08
01-MW4	10.65 (9.81*)	9.25 (10.09*)
01-MW5	9.40 (9.28*)	9.68 (9.80*)
01-MW6	8.55	9.63
01-MW7	10.00	9.23
01-MW7D	6.95	10.73
01-MW8	9.19	8.98
01-MW8D	7.85	10.61
01-MW9D	6.35	11.40
Ditch adjacent to 1-MW7	Datum on sediment surface was 7.69 ft.	Approximately 8.2

*Indicates free product level.

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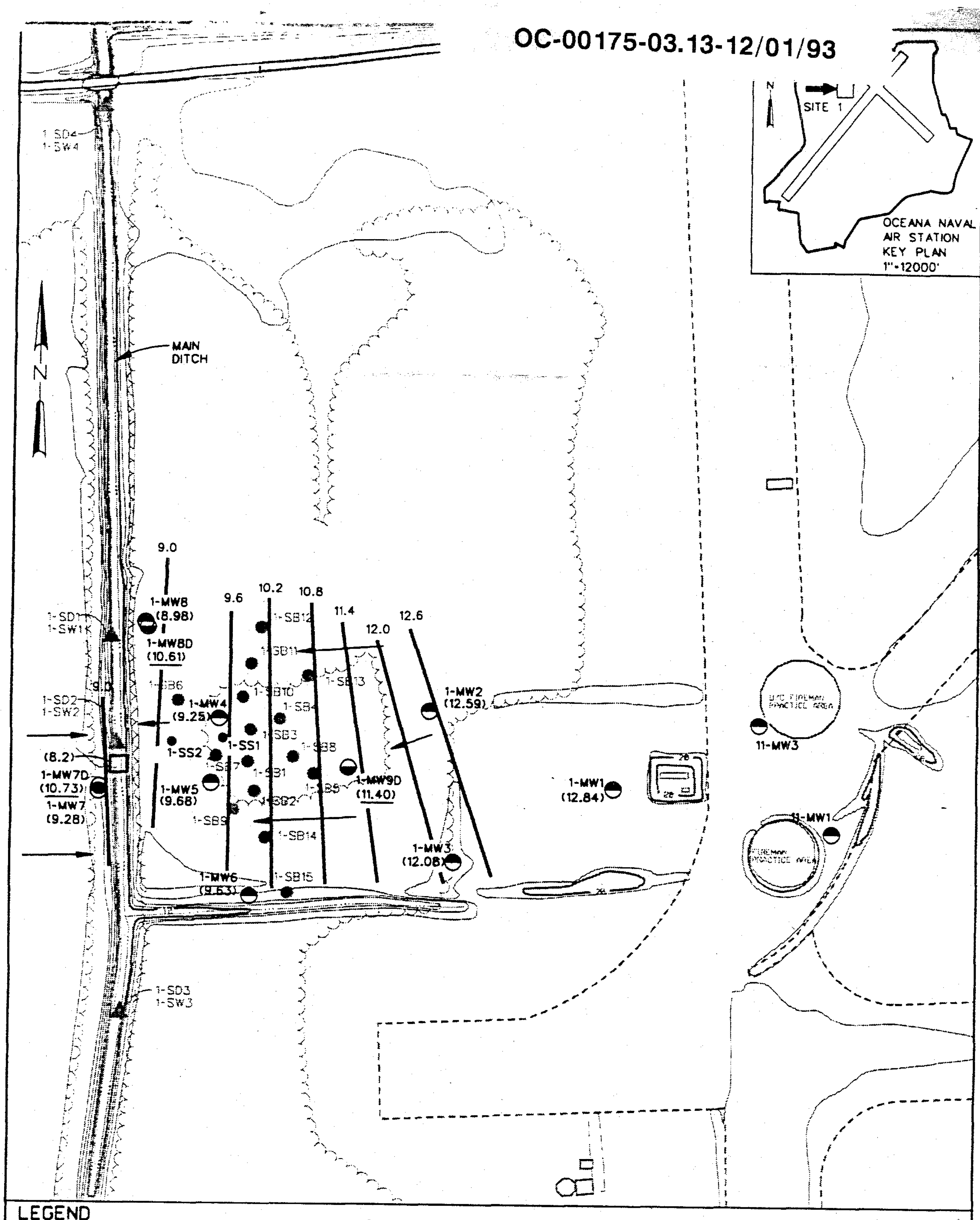

LEGEND

- SHALLOW MONITORING WELL
- DEEP MONITORING WELL
- SURFACE WATER ELEVATION MEASUREMENT
- ( ) WATER LEVEL ELEVATIONS, DEEP WELL DATA UNDERLINED
- DIRECTION OF GROUNDWATER FLOW

0 100 200 300
SCALE IN FEET

Figure 4-1-3
WATER TABLE ELEVATIONS WITH EQUIPOTENTIAL CONTOURS FOR THE SHALLOW AQUIFER AT SITE 1
JANUARY 26, 1993

CH2M HILL

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elevation in wells 1-MW7 and 1-MW8, located 15 to 25 feet from the ditch. This elevation suggests that water flowed towards the ditch from both sides in January 1993 and that any seepage face would be within a few inches of the water line.

The *in situ* hydraulic conductivity of the sediments was measured in the three deep wells and in shallow wells 1-MW6, 1-MW8, and 1-MW3 during the RFI by rising and falling head slug tests. Taken as a group, these tests give a general indication of the hydraulic conductivity of the aquifer in which the wells are screened. The test results are shown in Table 4-1-3. The arithmetic mean hydraulic conductivity indicated by these data was 4×10^{-3} cm/sec for the shallow clean sand and 7×10^{-5} cm/sec for the very fine silty sands of the Yorktown Formation.

The rate of shallow groundwater flow can be calculated by using Darcy's Law and estimating values of porosity, hydraulic conductivity, and horizontal gradient. Assuming a porosity of 0.20, a horizontal gradient (measured from 1-MW3 to 1-MW6) of 0.008, and an average hydraulic conductivity of 4×10^{-3} cm/sec (11.3 ft/day), the average linear velocity of groundwater is 160 linear ft/year. The rate of contaminant transport is expected to be considerably slower because the contaminants have a tendency to adsorb to the soil particle surfaces, which retards their movement. The degree of retardation depends on both the containment and soil properties.

Contamination and Extent

Soils

As recommended in the Interim RFI (CH2M HILL, 1990), an extensive soil sampling program was designed and implemented to characterize the nature and extent of soil contamination at this site. Fifteen soil borings were advanced to the depth of the water table and sampled at 2-foot intervals. The split-spoon samples were screened with an organic vapaor analyzer (OVA) and samples from nine boring were submitted to the laboratory for analysis. Lithologic descriptions, OVA readings, and other observations are listed in Appendix C, Table C-1. No samples from the first six soil borings (1-SB1 to SB6) were submitted for laboratory analysis; instead, these borings were used for early qualitative characterization. Figure 4-1-1 displays the soil boring locations, all of which were surveyed for horizontal control. The results of the horizontal survey are included in Appendix F.

The soil-boring program demonstrated that substantial soil contamination exists in the center of the site from boring 1-SB9 on the south to boring 1-SB12 on the north, but that contamination is limited on the east in 1-SB5 and 1-SB8 and to the south in 1-SB14 and 1-SB15. The contaminants detected were fuel-related semivolatiles and volatiles and minor amounts of PCBs and pesticides. The distribution of contamination in borings 1-SB7 to 1-SB15 and in shallow soil samples 1-SS1 and 1-SS2 is illustrated in Figure 4-1-4. The

Table 4-1-3
RESULTS OF HYDRAULIC CONDUCTIVITY TESTS AT SITE 1
February 1993
(All figures in cm/sec)

Monitoring Well	Average Hydraulic Conductivity (cm/sec)
1-MW3	5×10^{-3}
1-MW6	2×10^{-3}
1-MW7D	7×10^{-5}
1-MW8	5×10^{-3}
1-MW8D	1×10^{-4}
1-MW9D	5×10^{-5}

Notes:

2 tests were conducted at all monitoring wells, except 1-MW3 and 1-MW8, where 4 tests and 3 tests, respectively, were conducted. Detailed information is presented in Appendix E.

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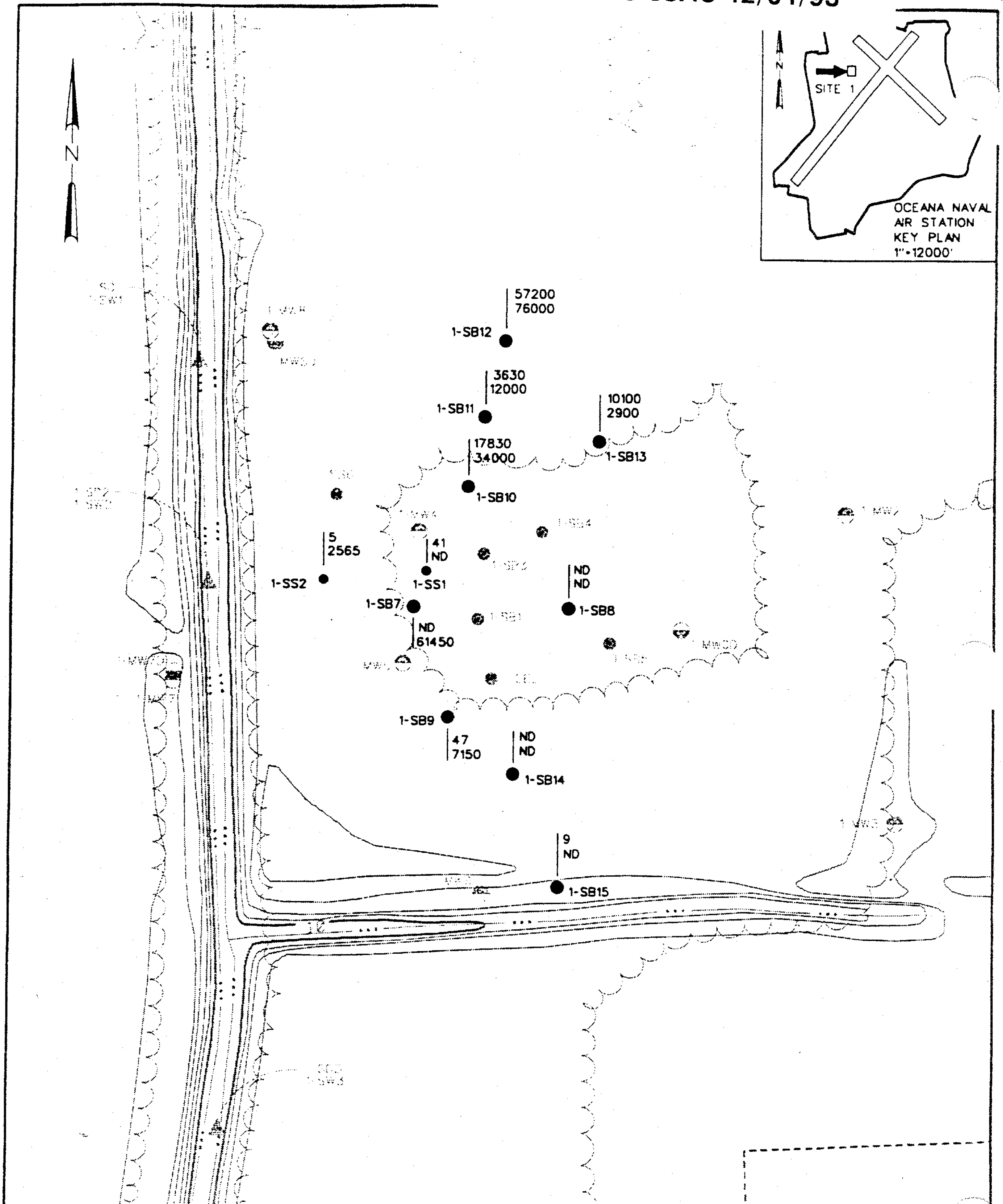

LEGEND

- SHALLOW MONITORING WELL
- DEEP MONITORING WELL
- SEDIMENT AND SURFACE WATER SAMPLING LOCATION
- SOIL SAMPLING LOCATION
- SOIL BORING LOCATION
- ND NOT DETECTED

BTEX
SEMIVOA/PAH

NOTE: ALL DATA IN ppb.
NO SAMPLES WERE COLLECTED FROM SOIL BORINGS 1-SB1 THROUGH 1-SB6.

Figure 4-1-4
ORGANIC CONTAMINANT CONCENTRATIONS IN SOIL AT SITE 1
JANUARY 1993

CH2M HILL

total concentrations of benzene, toluene, ethylbenzene, and xylenes (BTEX) and all detected semivolatiles or polynuclear aromatics (semivolatile/PAH) are shown next to each analytical sample location in Figure 4-1-4.

The first four soil borings (1-SB1 through 1-SB4) produced high OVA readings with some readings equaling or exceeding 1,000 parts per million (ppm). The higher OVA readings typically came from the sampling intervals between 4 and 8 feet. These samples also had strong to very strong fuel odors and left an oily sheen on the split spoons.

1-SB5 and 1-SB6 both delineate areas where organic contamination was low. The OVA readings from each 2-foot interval in 1-SB5 were substantially lower those previously recorded and no fuel odor was apparent. The low OVA readings subsequently were confirmed through laboratory analysis of a nearby soil boring (1-SB8), which did not contain BTEX, semivolatile, or polynuclear aromatic hydrocarbon (PAH) compounds. Although a slight fuel odor was apparent when 1-SB6 was reamed, the OVA readings typically were low relative to the readings from the first four soil borings. This area apparently is not contaminated with free-phase fuel but may be influenced by groundwater transport from fuel-contaminated areas to the east.

Analytical samples were collected from soil borings 1-SB7 through 1-SB15 after quantitative field screening for contamination. The highest OVA readings in each borehole typically were encountered from 4.0 to 8.0 feet, with readings exceeding 1,000 ppm at two locations (1-SB9 and 1-SB10). The laboratory results for organic analysis are listed in Table 4-1-4 and presented in Figure 4-1-4.

North of the central part of the site in borings 1-SB10, 1-SB11, 1-SB12, and 1-SB13, substantial contamination by BTEX, semivolatile/PAH compounds, and some PCBs was detected. This contamination suggests that the oil disposal locations may have extended farther north than previously believed on the basis of the photos of the oil pit. Groundwater flow from the area of known free product near wells 1-MW4 and 1-MW5 could not have transported fuels in this direction. Another possible explanation for the extensive contamination to the north is that the free-phase contamination may have spread out on the surface or in the unsaturated zone under the influence of gravity and surface contours. Because contamination in 1-SB12 was the highest of all soil borings, soil contamination clearly extends an unknown distance north of 1-SB12.

Soil contamination also was found to a lesser degree in borings south of well 1-MW5 and was confirmed in boring 1-SB7 in the center of the site. Low concentrations of pesticides were detected along with substantial semivolatile/PAH contamination in 1-SB7 in the center of the site. Low concentration of carbon disulfide and hexachlorinated dibenzofurans also were detected in 1-SB7. At 1-SB9, some BTEX and substantial concentrations of semivolatile/PAH compounds were detected but pesticides were absent. On the basis of the low results in 1-SB14 and 1-SB15, little soil contamination apparently exists south of 1-SB14. The BTEX concentration in the southernmost soil boring (1-SB15) was low (9 ppb) relative to other soil samples and no contamination was detected in 1-SB14.

Table 4-1-4
ORGANIC COMPOUNDS IN SOILS AT SITE 1
December 1992 to February 1993
(All data in μg/kg)

Analyte	1-SB7[e,f]	1-SB8[e]	1-SB9[e,f]		1-SB10	1-SB11	1-SB12	1-SB13[d]		1-SB14	1-SB15[e]	1-SS1	1-SS2
			Initial	Duplicate				Initial	Duplicate				
Volatile Organic Compounds													
Methylene Chloride	38	11	31 bj	31 b	380 bj	540 bj	670 bj	*	250 bj	190 bj	13 b	28 b	17 b
Acetone	66	22	110	120	*	2,100 b	*	2,100 b	2,300 b	2,200 b	23	20	8 j
Carbon Disulfide	10 j	*	*	*	*	*	*	*	*	*	*	8	4 j
Xylene (Total)	*	*	47	57	13,000	2,900	44,000	8,300	6,100	*	2 j	15	5 j
Ethylbenzene	*	*	*	*	4,000	460 j	6,400	1,800	1,300	*	*	1 j	*
Toluene	*	*	*	*	830 j	270 j	6,800	*	*	*	3 j	25	*
2-Butanone	*	*	*	*	*	*	*	*	*	*	*	72	*
Benzene	*	*	*	*	*	*	*	*	*	*	4 j	*	*
Semivolatile Compounds/Polynuclear Aromatic Compounds													
Naphthalene	21,000	*	1,200 j	3,900	*	*	31,000	*	*	*	*	*	*
2-Methylnaphthelene	38,000	*	4,800	12,000	34,000	12,000	45,000	2,900	6,300	*	*	*	*
Dibenzofuran	1,200 j	NA	200 j	540 j	NA	NA	NA	NA	NA	NA	NA	NA	N[illegible]
Fluorene	730 j	*	230 j	460 j	*	*	*	*	*	*	*	*	35[illegible]
Phenanthrene	520 j	*	240 j	640 j	*	*	*	*	*	*	*	*	26[illegible]
Di-n-Butylphthalate	*	NA	*	230 bj	NA	NA	NA	NA	NA	NA	NA	NA	N[illegible]
bis (2-Ethylhexyl)phthalate	*	NA	480 j	2,800	NA	NA	NA	NA	NA	NA	NA	NA	N[illegible]
Fluoranthene	*	*	*	*	*	*	*	*	*	*	*	*	4[illegible]
Pyrene	*	*	*	*	*	*	*	*	*	*	*	*	3[illegible]
Benzo (a) anthracene	*	*	*	*	*	*	*	*	*	*	*	*	1[illegible]
Chrysene	*	*	*	*	*	*	*	*	*	*	*	*	2[illegible]
Benzo (b) fluoranthene	*	*	*	*	*	*	*	*	*	*	*	*	2[illegible]
Benzo (k) fluoranthene	*	*	*	*	*	*	*	*	*	*	*	*	2[illegible]
Benzo (a) pyrene	*	*	*	*	*	*	*	*	*	*	*	*	2[illegible]
Indeno (1,2,3-cd) pyrene	*	*	*	*	*	*	*	*	*	*	*	*	170
Benzo (g,h,i) perylene	*	*	*	*	*	*	*	*	*	*	*	*	130

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Table 4-1-4
ORGANIC COMPOUNDS IN SOILS AT SITE 1
December 1992 to February 1993
(All data in μg/kg)

Analyte	1-SB7[e,f]	1-SB8[e]	1-SB9[e,f]		1-SB10	1-SB11	1-SB12	1-SB13[d]		1-SB14	1-SB15[a]	1-SS1	1-SS2
			Initial	Duplicate				Initial	Duplicate				
Pesticides/PCBs													
4,4'-DDE	2.0	NA	*	*	NA	NA	NA	NA	NA	NA	NA	NA	NA
4,4'-DDD	18	NA	*	*	NA	NA	NA	NA	NA	NA	NA	NA	NA
4,4'-DDT	3.4	NA	*	*	NA	NA	NA	NA	NA	NA	NA	NA	NA
Aroclor-1260	*	*	*	*	14 j	*	*	*	*	*	*	*	*
Aroclor-1254	*	*	*	*	*	11 j	27	*	7 j	*	*	140	*
Appendix IX Herbicides	*	NA	*	*	NA	NA	NA	NA	NA	NA	NA	NA	NA
Appendix IX Organophosphorus Pesticides	*	NA	*	*	NA	NA	NA	NA	NA	NA	NA	NA	NA
Appendix IX Dioxins	*	NA	*	*	NA	NA	NA	NA	NA	NA	NA	NA	
Appendix IX Furans:													
Hexachlorinated-Dibenzo Furans (Total)	0.30 c	NA	*	*	NA	NA	NA	NA	NA	NA	NA	NA	

Notes:

Analysis: 1-SB7 and 1-SB9 were analyzed for Appendix IX compounds; all other samples were analyzed for metals, PCBs, PAHs, and VOCs. All compounds not listed in their respective cat above were not detected in any samples.
QC sampling: 1-SB20 was QC for 1-SB9; 1-SB21 was QC for 1-SB13. The data for the field duplicate is listed with the data for the initial sample.
NA - Not analyzed
*Compound analyzed for but not detected
j - Estimated value; measured value is less than the quantitative detection limit
a - The sample VOC data were qualified as estimated during the data validation process because the sample was analyzed outside the holding time limit.
b - Compound found in laboratory blank associated with this sample
c - Reported value occurred below the linear range on the 5 point calibration curve.
d - The field duplicate PAH results were in poor correlation with the initial sample PAH results as determined by the data validation process. No qualification was performed.
e - The sample OC pesticide/PCB results were qualified as estimated as determined by the data validation process because the extraction holding times were exceeded.
f - The sample kepone results were qualified as estimated during the data validation process because the extraction holding times were exceeded.

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Two additional soil samples (1-SS1 and 1-SS2) were collected at Site 1 from a depth of 3 to 9 inches. The samples were collected to determine if shallow soil contamination was caused by the flood in the late 1960s during which the oil disposal pit overflowed and its contents washed downstream. The samples were placed between the suspected source area and drainage ditch. The analytical results, which are included with the soil boring results in Table 4-1-4, indicate that minor BTEX contamination is present in 1-SS1 (41 ppb) and 1-SS2 (5 ppb). In addition, a total of 2,565 ppb of 11 PAH compounds was detected in 1-SS2.

The inorganic results for the Site 1 soil samples are presented in Table 4-1-5. The metals detected were present at concentrations found naturally in soils or were close to the instrument detection limits.

Groundwater

The organic and inorganic results for Site 1 groundwater are presented in Tables 4-1-6 and 4-1-7. Contrary to the results of the soil sampling, PAH compounds were not detected in groundwater at Site 1. BTEX contamination was detected in 1-MW4 (67 ppb) and 1-MW5 (16 ppb) but was absent in all other wells. These concentrations are similar to those detected in previous investigations. The RFI BTEX results are shown in Figure 4-1-5. Well 1-MW4 contained 2 ppb of 1,1-DCA. The two deep monitoring wells, 1-MW8D and 1-MW9D, were free of contamination with the possible exception of chloroform, which was detected in both wells at 5 ppb. The groundwater from well 1-MW4, which is one of the wells with free product, was analyzed for Appendix IX pesticides and PCBs. No Appendix IX pesticides or PCBs were detected in the sample.

It is noteworthy that during sampling, free product was detected in 1-MW4 and 1-MW5. The thickness of free product in 1-MW4 and 1-MW5 was 0.12 and 0.84 feet, respectively. The floating free product in 1-MW4 was analyzed for VOCs, metals, PAHs, dioxin (2,3,7,8-TCDD), and PCBs. The analytical results, which are included in Table 4-1-6 under 1-MW4LN, indicate that the product contained xylene at 14,000 ppb and 3 PAH constituents at 1,200 to 2,000 ppb. No dense free product was detected in the well.

All monitoring wells were sampled for total and dissolved metals. Results are presented in Table 4-1-7. All metals concentrations were low. Beryllium was undetected in groundwater at a detection limit of 0.26 ppb.

In summary, groundwater contamination appears to be centered around 1-MW4 and 1-MW5 and is essentially absent to the north in well 1-MW8, to the south in 1-MW6, to the east in 1-MW9D, and across the ditch in 1-MW7. Vertically, contamination does not appear to have reached the screened zone of the three deep wells, with the possible exception of chloroform, a common laboratory contaminant. The absence of contaminants in all deep monitoring wells at Site 1 suggests that the vertical extent of contamination is limited. Because the results of the groundwater sampling from 1-MW7 and 1-MW7D were

Table 4-1-5
INORGANIC COMPOUNDS IN SOILS AT SITE 1
December 1992 to February 1993
(All data in mg/kg, ppm)

Analyte	1-SB7	1-SB8	1-SB9		1-SB10	1-SB11	1-SB12	1-SB13		1-SB14	1-SB15	1-SS1*	1-SS2
			Initial	Duplicate				Initial	Duplicate				
Aluminum	NA	1010	NA	NA	2,590	5,350	475	7,540	14,300	22,000	7,130	15,700	14,900
Antimony	13.0 b	< 2.6	< 4.1	< 4.2	< 2.4	< 2.5	< 2.7	< 2.5	< 2.6	3.6 b	< 2.6	<4.2 n	5.9 bn
Arsenic	1.8 b	1.3 b	2.1 b	2.6	0.56 b	1.2 b	0.44 b	0.76 b	1.4 b	1.4 b	0.57 b	3.0	3.5
Barium	24.3 b	6.0 b	75.9	97.0	29.6 b	23.9 b	3.0 b	29.1 b	51.1	52.5	43.5 b	67.2	78.8
Beryllium	0.11 b	0.08 b	0.52 b	0.74 b	0.07 b	0.17 b	< 0.05	0.28 b	0.39 b	0.56 b	0.45 b	0.49 b	0.54 b
Cadmium	0.72 b	< 0.73	< 0.70	< 0.72	< 0.66	< 0.70	< 0.74	< 0.69	1.3	< 0.77	< 0.71	< 0.70	
Calcium	NA	126 b	NA	NA	448 b	284 b	63.4 b	142 b	234 b	344 b	237 b	1,080	
Chromium	15.1	8.8	23.5	42.0	10.1	8.5	2.9	14.2	23.7	34.3	13.9	18.9	
Cobalt	1.8 b	< 0.80	3.1 b	4.8	1.3 b	1.1 b	< 0.82	2.3 b	3.4 b	3.0 b	2.8 b	3.1 b	
Copper	55.9	2.3 b	12.9	11.7	70.8	5.7 b	0.76 b	4.5 b	6.7	6.6	5.8 b	13.1	
Iron	NA	1,290	NA	NA	8,550	2,860	336	5,440	8,360	15,400	6,220	6,140	
Lead	138	1.7	29.6	16.0	14.6	42.3	1.1	0.78	9.6	8.9	8.1	45.5	
Magnesium	NA	181 b	NA	NA	195 b	404 b	65.0 b	815 b	1,070 b	1,140 b	1,230	961 b	
Manganese	NA	10.6	NA	NA	40.1	11.6	2.3 b	16.7	19.0	18.1	22.6	27.5	
Mercury	0.04 b	< 0.4	0.14	0.06 b	0.05 b	0.05 b	0.04 b	0.05 b	0.04 b	0.05 b	0.04 b	0.09 b	
Nickel	11.7	< 1.3	11.0	13.2	10.3	3.8 b	< 0.66	6.3 b	10.3	8.5 b	7.1 b	9.5 b	
Potassium	NA	< 164	NA	NA	179 b	296 b	186	491 b	642 b	782 b	549 b	666 b	
Selenium	< 0.43	< 0.44	< 0.46	< 0.47	< 0.41	0.62 b	< 0.46	< 0.43	< 0.45	< 0.48	< 0.44	0.65 b	
Silver	<0.46	< 0.48	< 0.50	< 0.51	< 0.45	< 0.48	< 0.50	< 0.47	< 0.49	< 0.52	< 0.48	< 0.51	
Sodium	NA	180 b	NA	NA	169 b	191 b	197	186	409 b	241 b	435 b	251 b	262 b
Thallium	<0.54	< 1.56	< 0.50	< 0.60	< 0.51	< 0.55	< 0.58	< 0.54	< 0.56	< 0.60	< 0.55	< 0.59	< 0.56

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Table 4-1-5
INORGANIC COMPOUNDS IN SOILS AT SITE 1
December 1992 to February 1993
(All data in mg/kg, ppm)

Analyte	1-SB7	1-SB8	1-SB9		1-SB10	1-SB11	1-SB12	1-SB13		1-SB14	1-SB15	1-SS1[a]	1-SS2
			Initial	Duplicate				Initial	Duplicate				
Vanadium	5.2 b	2.8 b	25.6	45.7	4.0 b	7.9 b	1.6	13.7	19.8	52.2	12.1	20.0	19.7
Zinc	257	6.1	34.4	33.6	117	26.1	< 2.4	16.7	25.1	23.5	24.4	52.9	85.1
Cyanide	< 0.1	NA	< 0.11	< 0.11	NA	NA	NA	NA	NA	NA	NA	NA	NA
Tin	27.5 b	4.3 b	4.6 b	< 3.3	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sulfide	18.5	NA	5.2	< 5.2	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes:

1-SB7 and 1-SB9 were analyzed for Appendix IX metals with cyanide and sulfide. All other samples were analyzed for TAL metals.
QC Sampling: 1-SB20 is a duplicate of 1-SB9, and 1-SB21 is a duplicate of 1-SB13. The results of the field duplicate's analysis are listed with initial sample results.
NA - Not analyzed.
a - The non-detect results of antimony were rejected during the data validation process because of spike recovery less than 30 percent.
b - The reported value obtained was less than the contract required detection limit (CRDL) but greater than or equal to the instrument detection limit (IDL).
< - The constituent was not detected at this IDL.
n - Poor prespike recovery.

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Table 4-1-6
ORGANIC COMPOUNDS IN GROUNDWATER AT SITE 1
RESULTS OF RFI AND PREVIOUS STUDIES
(All data in ppb)

Analyte	Detection Limit	1-MW3			1-MW4			1-MW4LN[a]	1-MW5		1-MW6	1-MW7	1-MW7D	1-MW8		1-MW8D	1-MW9D
		May 86	Aug. 90	Jan. 93	Aug. 90		Jan. 93	Jan. 93	Aug. 90	Jan. 93	Jan. 93	Jan. 93	Jan. 93	Jan. 93		Jan. 93	Jan 93
					Initial	Duplicate								Initial	Duplicate		
EDB	0.02	*	*	NA	*	*	NA	NA	*	NA	NA	NA	NA	NA	NA	NA	NA
Appendix IX Pesticide/PCB	0.02-2.0	NA	NA	NA	NA	NA	*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PCBs																	
Aroclor-1254	0.2, 0.5	*	*	*	0.4	0.3	*	*	*	*	*	*	*	*	NA	*	
Aroclor-1260	0.2, 0.5	*	*	*	0.2	*	*	*	*	*	*	*	*	*	NA	*	
Appendix IX Dioxin/Furans	.000032-.000011	NA	NA	NA	NA	NA	*	*	NA	NA	NA	NA	NA	NA	NA	NA	
2,3,7,8-TCDD		NA	NA	NA	NA	NA	NA	*	NA	NA	NA	NA	NA	NA	NA	NA	
TCDD	--	<0.00021	<0.0007	NA	<0.0038	<0.0017	NA	NA	<0.0008	NA	NA	NA	NA	NA	NA	NA	
Oil and Grease	3,000	15,000	NA	NA	NA	NA	NA	NA	NA	2,800	<100	NA	NA	NA	NA	NA	
TPH	60-8,060 a	NA	140	NA	254,000	307,000	NA	NA	6,770	NA	NA	NA	NA	NA	NA	NA	
Volatile Organic Compounds																	
Acetone	10	*	6 bj	5 j	16 b	15 b	*	30000 j	55 b	7 j	5 bj	8 j	35	6 bj	*	25 b	
Methylene Chloride	5	*	6 bj	1 bj	25 b	5 b	3 bj	8200 bj	3 bj	3 bj	4 bj	2 bj	2 bj	13 b	9 b	14 b	
Benzene	5	*	*	*	4 j	*	6	*	1 j	1 j	*	*	*	*	*	*	
Carbon Disulfide	5	*	*	*	*	7	*	*	1 j	*	*	*	*	*	*	*	
Ethylbenzene	5	*	*	*	9	42	10	*	3 j	3 j	*	*	*	*	*	*	
4-Methyl-2-pentanone	10	*	*	*	*	*	*	*	3 c	*	*	*	*	*	*	*	
Xylenes (Total)	5	*	*	*	26	120	50	14000 j	14	12	*	*	*	*	*	*	
Chloroform	5	*	*	*	*	*	*	*	*	*	*	*	*	*	*	5	
Toluene	5	*	*	*	*	*	1 j	*	*	*	*	*	*	*	*	*	[illegible]
1,1-Dichloroethane	5	*	*	*	*	*	2 J	*	*	*	*	*	*	*	*	*	*

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Table 4-1-6
ORGANIC COMPOUNDS IN GROUNDWATER AT SITE 1
RESULTS OF RFI AND PREVIOUS STUDIES
(All data in ppb)

Analyte	Detection Limit	1-MW3			1-MW4			1-MW4LN[a]	1-MW5		1-MW6	1-MW7	1-MW7D	1-MW8		1-MW8D	1-MW9D
		May 86	Aug. 90	Jan. 93	Aug. 90		Jan. 93	Jan. 93	Aug. 90	Jan. 93	Jan. 93	Jan. 93	Jan. 93	Jan. 93		Jan. 93	Jan 93
					Initial	Duplicate								Initial	Duplicate		
Polynuclear Aromatic Compounds																	
Naphthalene	2	NA	NA	*	NA	NA	NA	1,200	NA	69	*	*	*	*	*	*	*
2-Methylnapthalene	2	NA	NA	*	NA	NA	NA	1,400	NA	54	*	*	*	*	*	*	*
1-Methylnapthalene	2	NA	NA	*	NA	NA	NA	2,000	NA	48	*	*	*	*	*	*	
Appendix IX Semivolatiles	10, 50	NA	NA	NA	NA	NA	*	NA	NA	NA	NA	NA	NA	NA	NA	NA	
Appendix IX Organophosphorous Pesticides	1	NA	NA	NA	NA	NA	*	NA	NA	NA	NA	NA	NA	NA	NA	NA	
Appendix IX Herbicides	0.5 - 2.5	NA	NA	NA	NA	NA	*	NA	NA	NA	NA	NA	NA	NA	NA	NA	

Notes:

All volatile organic compounds, PCBs, PAHs, and Appendix IX Series Compounds (to include: volatiles, semivolatiles, pesticides/PCBs, organophosphorous pesticides, herbicides, and dioxin/furans) that are not listed in the table above were below detection limits in samples.

A distinction is made between Appendix IX Pesticide/PCBs analysis and regular PCB analysis. The same principle applies to TCDD analysis and Appendix IX Dioxin/Furans analysis. The Appendix IX lists are typically longer and therefore provide for the detection compounds. 1-MW4 received Appendix IX analysis. 1-MW4LN is the analysis of the free product found in well.

EDB - Ethylene Dibromide
TCDD - 2,3,7,8-dioxin
TPH - Total Petroleum Hydrocarbons
NA - Not analyzed

a - Detection limit range for TPH samples is particular to this site
b - Compound found in laboratory blank as well as sample; sample concentration is less than 10 times blank concentration.
c - Reported value occurred below the linear range on the 5 point calibration curve.
d - Sample PAH and OC Pesticide/PCB results were qualified as estimated during the data validation process because the extraction holding times were exceeded.
j - Estimated value. The measured value is less than the accurately quantitative detection limit.
*Concentration below detection limit
(--) No detection limit available

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Table 4-1-7
INORGANIC COMPOUNDS IN GROUNDWATER AT SITE 1
January 1993
(All data in ppb)

Analyte	1-MW3		1-MW4		1-MW5		1-MW6		1-MW7		1-MW4LN[a]
	Total	**Dissolved**	**Total**	**Dissolved**	**Total**	**Dissolved**	**Total**	**Dissolved**	**Total**	**Dissolved**	**Total**
Aluminum	2,760	98.2[b]	NA	NA	222	35.6[b]	812	36.5[b]	2,170	236	47,000
Antimony	<16.4	<16.4	<16.4	<16.4	<16.4	<16.4	<16.4	<16.4	<16.4	<16.4	<3,300
Arsenic	5.3[b]	4.6[b]	2.2[b]	3.9[b]	1.6[b]	2.6[b]	0.98[b]	0.95[b]	2.5[b]	1.8[b]	930[b]
Barium	26.7[b]	12.8[b]	76.3[b]	75.1[b]	25.5[b]	28.6[b]	18.7[b]	15.0[b]	13.4[b]	6.2[b]	24,400[b]
Beryllium	<0.26	<0.26	<0.26	<0.26	<0.26	<0.26	<0.29	<0.26	<0.26	<0.26	<50
Cadmium	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<550
Calcium	7,540	7,620	NA	NA	19,300	19,800	26,800	27,500	60,500	52,600	227,000[b]
Chromium	6.8[b]	<2.8	3.8[b]	3[b]	<2.8	<2.8	5.5[b]	<2.8	7.5[b]	<2.8	1,100[b]
Cobalt	<2.6	<2.6	<2.6	<2.6	<2.6	2.8[b]	<2.6	<2.6	3.2[b]	<2.6	<530
Copper	9.8[b]	<1.2	<1.2	5.6[b]	<1.2	3.1[b]	<1.2	<1.2	3.9[b]	<1.2	7,500
Iron	8,740	7,310	NA	NA	13,400	12,700	6,300	5,700	8,920	6,360	41,500
Lead	3.0	<1.7	1.8[b]	<1.7	2.1[b]	<1.7	<1.7	<1.7	2.8[b]	3.0	81,000
Magnesium	10,700	10,300	NA	NA	9,130	9,550	10,500	10,300	12,700	10,900	5,800[b]
Manganese	345	348	NA	NA	166	165	304	303	518	446	3,700[b]
Mercury	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.01
Nickel	<9.4	<9.4	<9.4	<9.4	9.4[b]	<9.4	<9.4	<9.4	<9.4	<9.4	<1,900
Potassium	<934	1,970[b]	NA	NA	2,090[b]	3,100[b]	1,150[b]	2,870[b]	2,750[b]	1,410[b]	<187,000
Selenium	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<370
Silver	<2.0	<2.0	<2.0	2.7[b]	<2.0	2.3[b]	<2.0	<2.0	2.4[b]	<2.0	<400

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Table 4-1-7
INORGANIC COMPOUNDS IN GROUNDWATER AT SITE 1
January 1993
(All data in ppb)

Analyte	1-MW3		1-MW4		1-MW5		1-MW6		1-MW7		1-MW4LN[a]
	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total
Sodium	20,100	21,600	NA	NA	16,700	18,400	20,800	22,500	31,100	27,700	280,000[b]
Thallium	<2.3	<2.3	<2.3	<2.3	<2.3	<2.3	<2.3	<2.3	<2.3	<2.3	<460
Vanadium	5.7[b]	<2.6	<2.6	<2.6	<2.6	3.0[b]	3.0[b]	<2.6	5.4[b]	<2.6	2,900[b]
Zinc	22.4	19.4[b]	26.2	37.2	41.2	11.6[b]	16.9[b]	16.6[b]	18.3[b]	11.8[b]	2,600[b]
Tin	NA	NA	<12.7	<12.7	NA	NA	NA	NA	NA	NA	NA
Cyanide	NA	NA	<1.4	NA	NA	NA	NA	NA	NA	NA	NA
Sulfide	NA	NA	200	NA	<100	NA	<100	NA	NA	NA	NA

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Table 4-1-7
INORGANIC COMPOUNDS IN GROUNDWATER AT SITE 1
January 1993
(All data in ppb)

Analyte	1-MW7D		1-MW8				1-MW8D		1-MW9D	
			Initial		Duplicate					
	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved
Aluminum	2,290	29.9[b]	284*	79.7[b]	396	<24.3	2,330	53.0[b]	1,060	88.1[b]
Antimony	<16.4	<16.4	<16.4	<16.4	<16.4	<16.4	<16.4	<16.4	<16.4	<16.4
Arsenic	3.1[b]	2.7[b]	<0.68	<0.68	<0.68	<0.68	<0.68	0.98[b]	1.4[b]	1.4[b]
Barium	28.4[b]	19.0[b]	6.3[b]	6.5[b]	8.0[b]	4.8[b]	25.1[b]	17.5[b]	20.1[b]	16.1[b]
Beryllium	<0.26	<0.26	<0.26	<0.26	<0.26	<0.26	<0.26	<0.26	<0.26	<0.26
Cadmium	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8
Calcium	94,200	97,400	66,500	65,200	65,300	65,700	88,900	88,000	88,600	88,700
Chromium	9.2[b]	<2.8	3.1[b]	<2.8	2.9[b]	<2.8	7.3[b]	<2.8	8.5[b]	<2.8
Cobalt	3.7[b]	<2.6	<2.6	<2.6	<2.6	<2.6	<2.6	2.7[b]	<2.6	<2.6
Copper	11.8[b]	<1.2	<1.2	4.8[b]	<1.2	5.3[b]	<1.2	6.2[b]	3.0[b]	<1.2
Iron	5,480	2,470	10,500	9,570	9,980	9,430	4,300	732	2,500	1,170
Lead	4.0	<1.7	<1.7	<1.7	<1.7	<1.7	4.3	2.1[b]	2.5[b]	<1.7
Magnesium	11,700	11,200	17,300	17,600	17,400	17,300	11,700	11,300	11,000	10,400
Manganese	410	388	685	671	657	663	340	302	338	322
Mercury	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07
Nickel	10.6[b]	<9.4	10.5[b]	<9.4	10.1[b]	<9.4	<9.4	<9.4	<9.4	<9.4
Potassium	7,090	6,320	2,130[b]	2,550[b]	2,050[b]	1,730[b]	7,230	7,620	6,850	7,380
Selenium	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8
Silver	2.7[b]	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0

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Table 4-1-7
INORGANIC COMPOUNDS IN GROUNDWATER AT SITE 1
January 1993
(All data in ppb)

Analyte	1-MW7D		1-MW8				1-MW8D		1-MW9D	
			Initial		Duplicate					
Sodium	28,900	28,400	37,400	35,900	36,300	36,000	28,700	28,600	24,700	26,400
Thallium	<2.3	<2.3	<2.3	<2.3	<2.3	<2.3	<2.3	<2.3	<2.3	<2.3
Vanadium	6.8[b]	<2.6	<2.6	<2.6	<2.6	<2.6	6.2[b]	<2.6	5.7[b]	<2.6
Zinc	36.4	<9.0	16.7[b]	12.4[b]	14.2[b]	19.8[b]	30.7	12.6[b]	13.3[b]	13.1[b]
Tin	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cyanide	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sulfide	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes:

1-MW4 was submitted for Appendix IX metals analysis with cyanide and sulfide. All other samples were analyzed for total metals and dissolved metals.
QC Sampling - 1MW-30 is the duplicate site of 1-MW8.
[a]The reported values are in μg/kg. The sample was analyzed as a sludge because the free product was very dense.
[b]The reported value obtained was less than the CRDL but greater than or equal to the IDL.
< - The constituent was not detected at this IDL.
*Indicates duplicate analysis not within control limits.

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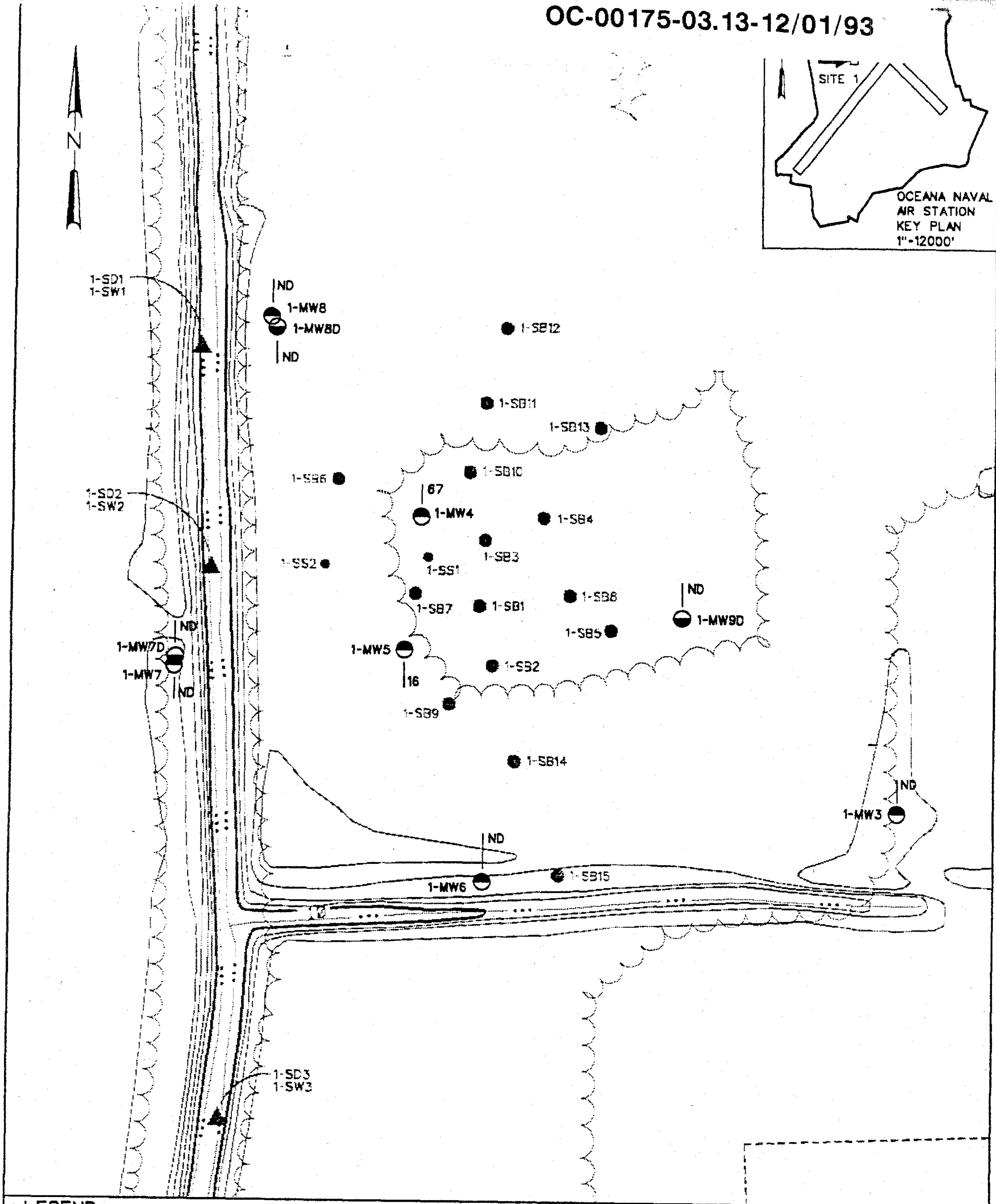

LEGEND

| BTEX CONCENTRATIONS

SHALLOW MONITORING WELL

DEEP MONITORING WELL

ND NOT DETECTED

NOTE: ALL DATA IN ppb

SOIL SAMPLING LOCATION

SEDIMENT AND SURFACE WATER SAMPLING LOCATION

0 50 100 150

SCALE IN FEET

Figure 4-1-5
BTEX CONCENTRATIONS
IN GROUNDWATER
AT SITE 1
JANUARY 1993

CH2M HILL

0368k013.dgn
12-Apr-1993

nondetects and because the stream level was lower than the groundwater level adjacent to the ditch, the main drainage ditch at this site receives groundwater and may act as a hydrologic divide limiting the contaminant plume on the west.

Surface Water and Sediment

The results of surface water and sediment sampling of the drainage ditch at Site 1 are presented in Tables 4-1-8 through 4-1-11. All surface water and sediment samples were submitted for analysis of volatiles, PAHs, PCBs, and total metals. No pesticides were analyzed in surface water or sediments; however, no pesticides were detected in the most contaminated well at Site 1 (1-MW4) and only minor concentrations of common persistent pesticide species (DDD, DDE, DDT) were detected at 2 to 18 ppb. No organic contaminants were detected in the four surface water samples (1-SW1 through 1-SW4). The organic results agree with the surface water results of previous investigations.

Zinc, nickel, cobalt, barium and arsenic were the only trace metals detected. Common major constituents of soils and pore water, such as aluminum, sodium, calcium, and iron were abundant but not elevated. These concentrations were low and did not exceed any applicable federal or state standards. Monthly VPDES monitoring for total organic carbon (TOC), oil and grease, and pH approximately 3,500 feet downstream of Site 1 from January 1992 to March 1993 generally did not indicate contamination. TOC, pH, and oil and grease ranged from 2.65 to 16 ppm, 5.99 to 7.75 ppm, and nondetect to 278 ppm, respectively, during this period. The January 1993 oil and grease value of 278 mg/l was anomalous in that the next highest reading was 11.0 mg/l and TOC was only 5.0 mg/l during the same sampling event (NAS Oceana, 1993). Comprehensive analyses done for the VPDES permit application did not show contamination (Bullard, 1993).

Organic compounds also were largely undetected in sediments. No organic contaminants were detected in either 1-SD1 or 1-SD3. A very low concentration of total xylenes (3 ppb) was detected in 1-SD2. Only two PAH compounds, fluoranthene and pyrene, were detected, both in 1-SD4 at concentrations of 400 ppb. During the Interim RFI, 2-butanone, ethylbenzene, and toluene were detected; however, these compounds were absent during this round of sampling. All metals on the analyte list except for antimony, selenium, and thallium were detected, but none were present at concentrations considerably above detection limits.

Health and Environmental Assessment

An HEA was performed at each of the 17 sites. The HEA is described at the beginning of this chapter and in Appendix A. Constituents detected at Site 1 that exceeded potentially applicable federal standards and guidelines are presented in Table 4-1-12. Benzo(a)pyrene, benzene, PCBs (Aroclor-1254), and beryllium where the only analytes that exceeded human health-based criteria. The benzo(a)pyrene concentration of 230 ppb in soil sample 1-SS2 exceeded the health-based criterion for carcinogens of 60.9 ppb. Benzene in the

Table 4-1-8
ORGANIC COMPOUNDS IN SURFACE WATER AT SITE 1
RESULTS OF RFI AND PREVIOUS STUDIES
(All data in ppb)

Parameter	Detection Limit	1-SW1		1-SW2			1-SW3		1-SW3&	1-SW4
		Aug. 90	Jan. 93	Aug. 90	Jan. 93		Aug. 90		Jan. 93	Jan. 93
					Initial	Duplicate	Initial	Duplicate		
PCBs	0.20-2.0 a	*	*	*	*	NA	*	*	*	*
TPH	50	540	NA	*	NA	NA	*	*	NA	NA
Dioxins	.000058	NA	*	NA	NA	NA	NA	NA	NA	NA
Volatile Organic Compounds										
Methylene Chloride	5	9 b	13 b	5 b	2 bj	NA	11 b	NA	2 bj	3 bj
Acetone	10	9 bj	7 bj	7 bj	7 j	NA	10 b	NA	8 j	*
Carbon Disulfide	5	3 j	*	*	*	NA	*	NA	*	*
Chloroform	5	2 j	*	*	*	NA	*	NA	*	*
Xylenes (Total)	5	2 j	*	*	*	NA	*	NA	*	*
Bromodichloromethane	5	*	*	*	*	NA	1 j	NA	*	*
Polynuclear Aromatic Hydrocarbons	2	NA	*	NA	*	*	NA	NA	*	*

Notes:

All volatile organic and polynuclear aromatic compounds not listed above were not detected in any samples.
& - The sampling location for 1-SW3/1-SD3 in January 1993 was farther upstream than in August 1990.
TPH - Total Petroleum Hydrocarbons
NA - Not analyzed; VOC duplicate not collected at this site.
a - Detection limit range in water for Aroclor-1016, 1221, 1232, 1242, 1248, 1254, and 1260.
b - Compound was found in laboratory blank as well as in sample; sample concentration was less than 10 times the blank concentration.
j - Estimated value. Measured value is less than the accurately quantitative limit.

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Table 4-1-9
ORGANIC COMPOUNDS IN SEDIMENT AT SITE 1
RESULTS OF RFI AND PREVIOUS STUDIES
(All data in ppb)

Parameter	1-SD1		1-SD2		1-SD3		1-SD3 &	1-SD4
	Aug. 90	Jan 93	Aug. 90	Jan. 93	Aug. 90		Jan. 93	Jan. 93
					Initial	Duplicate		
PCBs	*	*	*	*	*	*	*	*
TPH	1,260,000	NA	1,180,000	NA	153,000	85,300	NA	NA
Dioxin	NA	*	NA	NA	NA	NA	NA	NA
Volatile Organic Compounds								
Methylene Chloride	*	12[b]	24[c]	11[b]	90[c]	330[c]	19[b]	32[b]
Acetone	*	3[bj]	410[c]	12[j]	31[b]	24[b]	23	23
2-Butanone (MEK)	44	*	110	*	14[j]	*	*	*
Ethylbenzene	95	*	*	*	*	*	*	*
Xylenes (Total)	110	*	*	3[j]	*	*	*	*
Toluene	*	*	*	*	23	*	*	*
Polynuclear Aromatics (PAHs)								
Fluoranthene	NA	*	NA	*	NA	NA	*	400
Pyrene	NA	*	NA	*	NA	NA	*	400

Notes:

All volatile and polynuclear aromatic compounds not reported were below detection limits in all samples.
& - The 1-SD3 sampling location was farther upstream in 1993 than in 1990.
TPH - Total Petroleum Hydrocarbons
NA - Not analyzed; VOC duplicate not collected at this site.
* - Compound was analyzed but not detected.
[a]Detection limit range in water for Aroclor-1016, 1221, 1232, 1242, 1248, 1254, and 1260
[b]Compound was found in laboratory blank as well as in sample; sample concentration was less than 10 times the blank concentration.
[d]Detection limit range in soil for TPH samples was particular to this site.
[c]Compound was found in laboratory blank as well as in sample; sample concentration was more than 10 times the blank concentration.
[j]Estimated value. Measured value is less than the accurately quantitative limit.

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Table 4-1-10
INORGANIC COMPOUNDS IN SURFACE WATER AT SITE 1
January 1993 to February 1993
(All data in ppb)

Analyte	1-SW1	1-SW2	1-SW3	1-SW4
Aluminum	267	192[b]	200[b]*	376
Antimony	<16.4	<16.4	<16.4	<16.4
Arsenic	2.1[b]	1.9[b]	4.4[b]	3.8[b]
Barium	27.2[b]	24.8[b]	27	27.2[b]
Beryllium	<0.26	<0.26	<0.26	<0.26
Cadmium	<2.8	<2.8	<2.8	<2.8
Calcium	7,350	7,040	7,510	7,150
Chromium	<2.8	<2.8	<2.8	<2.8
Cobalt	<2.6	3.9[b]	3.9[b]	4.3[b]
Copper	<1.2	<1.2	<1.2	<1.2
Iron	2,500	2,150	2,760	2,560
Lead	<1.7	<1.7	<1.7	<1.7
Magnesium	5,790	5,830	5,500	5,920
Manganese	109	106	114	93.9
Mercury	<0.07	<0.07	<0.07	<0.07
Nickel	11.1[b]	<9.4	9.4[b]	<9.4
Potassium	<934	<934	<934	<934
Selenium	<1.8	<1.8	<1.8	<1.8
Silver	<2.0	<2.0	<2.0	<2.0
Sodium	12,900	13,200	14,200	12,300
Thallium	<2.3	<2.3	<2.3	<2.3
Vanadium	<2.6	<2.6	<2.6	<2.6
Zinc	15.5[b]	32.5	16.5[b]	16.2[b]

Notes:

[b]The reported value obtained was less than the CDRL, but greater than or equal to the IDL.
< - The constituent was not detected at this IDL.
*Duplicate analysis not within control limits.
[n]Spiked sample recovery not within control limits.

Table 4-1-11
INORGANIC COMPOUNDS IN SEDIMENT AT SITE 1
January 1993 to February 1993
(All data in ppm)

Analyte	1-SD1	1-SD2[a]	1-SD3[a]	1-SD4[a]
Aluminum	198	269	1,280	1,330
Antimony	<4.0[n]	<4.0	<4.8	<4.5
Arsenic	0.62[b]	1.2[b]	0.89[b]	2.3[b]
Barium	2.9[b]	2.5[b]	9.2[b]	8.9[b]
Beryllium	<0.06	<0.06	0.15[b]	0.11[b]
Cadmium	<0.68	<0.67	<0.81	<0.76
Calcium	248[b]	125[b]	520[b]	507[b]
Chromium	1.4[b]	1.1[b]	3.5	2.8
Cobalt	<0.65	< 0.65	1.9[b]	1.5[b]
Copper	<0.30[n]*	0.64[b]	2.5[b]	1.9[b]
Iron	662	813	883	1,400
Lead	0.67[bn]	0.78	1.8	2.3
Magnesium	38.3[b]	37.4[b]	187[b]	183[b]
Manganese	4.5	1.8[b]	6.1	13.2
Mercury	< 0.03	0.03[b]	0.05[b]	0.05[b]
Nickel	<2.3	<2.3	3.6[b]	<2.6
Potassium	<229	<228	307[b]	<256
Selenium	<0.45	<0.45	<0.54	<0.50
Silver	0.50[b]	<0.40	<0.58	<0.55
Sodium	243[b]	186[b]	294[b]	230[bv]
Thallium	<0.57	<0.57	<0.68	<0.64
Vanadium	1.3[b]	0.66[b]	3.4[b]	2.7[b]
Zinc	3.7[b]*	4.8[b]	10.5	15.3

Notes:

[a]The non-detect results of antimony were rejected during the data validation process because of spike recoveries less than 30 percent.
[b]The reported value obtained was less than the CDRL, but greater than or equal to the IDL.
< = The constituent was not detected at this IDL.
*Duplicate analysis not within control limits.
[n]Spiked sample recovery not within control limits.

Table 4-1-12
ORGANIC AND INORGANIC CONSTITUENTS DETECTED AT SITE 1 THAT EXCEEDED POTENTIALLY APPLICABLE FEDERAL STANDARDS AND GUIDELINES
January 1993
(All concentrations in ppb)

Human Health Assessment

Compound	Location Detected	Concentration	Health-Based Criteria for Carcinogens	Health-Based Criteria for Systemic Toxicants	MCL	MCLG	Proposed RCRA Action Limit
Aroclor-1254	Soil: 1-SS1	140	91	NS	NA	NA	90
Beryllium	Soils: 1-SB9 1-SB11 1-SB13 1-SB14 1-SB15 1-SS1 1-SS2	 520[b] 170[b] 280[b] 560[b] 450[b] 490[b] 540[b]	143	400,000	NA	NA	200
Benzo(a)pyrene	Soil: 1-SS2	230	60.9	NS	NA	NA	NS
Benzene	Groundwater: 1-MW4	6	NA	NA	5	0	NS

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Table 4-1-12
ORGANIC AND INORGANIC CONSTITUENTS DETECTED AT SITE 1 THAT EXCEEDED POTENTIALLY APPLICABLE FEDERAL STANDARDS AND GUIDELINES
January 1993
(All concentrations in ppb)

Ecological Assessment[a,c]

	Medium Detected	Maximum Concentration	NOAA ER-M Sediment Guidelines	EPA Human-Health Criteria for Ingestion of Water and Fish	Proposed RCRA Action Limit	Eastern United States Soil Mean
Iron	Soil Surface Water	17,300,000 2,760	NA NA	NA 300	NS NS	14,000,000 NA
Mercury	Sediment Soil	50 230	1,300 NA	NA NA	20,000 20,000	NA 81
Antimony	Soil	13,000	NA	NA	30,000	520
Chromium (total)	Soil	42,000	NA	NA	NS	33,000
Copper	Soil	70,800	NA	NA	NS	13,000
Arsenic	Soil Surface Water	3.5 4.4	NA NA	NA 0.0022	80 50	4.8 NA
Bromodichloro-methane	Surface Water	1[d]	NA	NS	0.03	NA
Chloroform	Surface Water	2	NA	0.19	NS	NA
Lead	Soil	138,000	NA	NA	NS	14,000
Nickel	Soil	13,200	NA	NA	2,000,000	11,000
Selenium	Soil	870	NA	NA	NS	300
Vanadium	Soil	52,200	NA	NA	NS	43,000

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Table 4-1-12
ORGANIC AND INORGANIC CONSTITUENTS DETECTED AT SITE 1 THAT EXCEEDED POTENTIALLY APPLICABLE FEDERAL STANDARDS AND GUIDELINES
January 1993
(All concentrations in ppb)

	Medium Detected	Maximum Concentration	NOAA ER-M Sediment Guidelines	EPA Human-Health Criteria for Ingestion of Water and Fish	Proposed RCRA Action Limit	Eastern United States Soil Mean
Zinc	Soil	257,000	NA	NA	NS	40,000
Tin	Soil	27,500	NA	NA	NS	860

Notes:

Compounds that were detected and exceeded potentially applicable federal standards are included in this table. The inorganics listed as less than a given concentration were not detected in the sample above the instrument detection level (IDL) but are included for comparison to guidelines. See Appendix A.
The health-based criteria for systemic toxicants and carcinogens were extracted from the *RFI Guidance Document* EPA 530/SW-89-031.
The proposed RCRA action levels were listed in the *Federal Register* July 27, 1990.
The IDLs for antimony, mercury, cadmium and thallium in groundwater were slightly above the MCL, or in the case of cadmium above the Virginia Groundwater Standard. Some inorganics cannot be quantified down to existing standards.
NA = Not applicable to the sample medium
NS = No standard
[a]Based on the maximum concentrations from all sampling locations at Site 1.
[b]The concentration is below the CRDL, but greater than the IDL.
[c]See Appendix A for discussion.
[d]Estimated value below accurate quantitation limit.

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groundwater in well 1-MW4 was detected at 6 ppb, which exceeds the groundwater MCL of 5 ppb. PCBs were present in the shallow soil sample 1-SS1 at a concentration of 140 ppb, which is higher than both the proposed RCRA action level (90 ppb) and the health-based criterion for carcinogens. No other PCB soil concentrations were above these criteria. No other organic contaminants that were detected in either the soil, groundwater, surface water, or sediment exceeded federal human-health standards.

Beryllium, the only inorganic analyte to exceed human-health standards, was detected in seven soil samples at concentrations of 0.07 to 0.56 ppm. The concentrations in these soils exceeded the health-based criterion for carcinogens of 0.143 ppm and the proposed RCRA action level of 0.2 ppm. Because beryllium is present at these concentrations at so many locations at Site 1 and throughout the station, beryllium concentrations may be close to guidelines even in uncontaminated background areas on the station. Data published by the U.S. Geological Survey lists the mean background concentration of beryllium in soils in the eastern United States as 0.55 ppm (Shacklette and Boerngen, 1984). Only one soil sample at Site 1 was above this background concentration.

Iron and arsenic were the only inorganics detected in surface water at Site 1 at concentrations above potentially applicable ecological standards. The concentration of iron was highest in 1-SW3 (2,760 ppb) but also was above the human-health criterion for ingestion of water and fish of 300 ppb in the other three surface water samples (2,150 to 2,560 ppb). Arsenic concentrations in all four surface water samples ranged from 1.9 to 4.4 ppb and all were above the human-health criterion for ingestion of water and fish of 0.0022 ppb. This potentially applicable standard also is considerably less than the instrument detection limit for arsenic. The human-health values for exposure through ingestion of contaminated water and aquatic organisms are assumed to underestimate environmental risk when applied to terrestrial organisms because of differences in biomass and ingestion rates. However, because the route of exposure and bioavailability is assumed to be the same in both cases, these criteria, although designed for human health, also identify potential risk for effects to terrestrial organisms from surface water through ingestion of water and aquatic life.

Chloroform and bromodichloromethane were detected in trace amounts in the historical data record for surface water. Chloroform was detected at 2 ppb in 1990 but was undetected in 1993 and bromodichloromethane was undetected in a 1990 duplicate and in all samples in 1993. These two organics are probably not present in the surface water at Site 1, but may be caused instead by slight lab contamination of a limited number of samples.

Contaminant concentrations in sediments were compared to the National Oceanic and Atmospheric Administration (NOAA) sediment guidelines (Long and Morgan, 1991). Observed metals concentrations in sediments at Site 1 did not exceed NOAA sediment guidelines.

Maximum arsenic concentrations of 3.5 ppm in soil did not exceed proposed RCRA action levels of 80 ppm or mean concentrations in the eastern United States (Shacklette and

Boerngen, 1984) but were above risk-based concentration limits calculated by toxicologists at the Region III office of the EPA (Smith, 1993). These calculated screening values were 0.68 ppm for residential soil and 1.6 ppm for commercial/industrial soils. However, because the mean concentration in the eastern United States (4.8 ppm) also is above both standards, the Site 1 concentrations of arsenic in soil are likely background concentrations unrelated to contamination.

Soil concentrations of several inorganic constituents at Site 1 were above mean background concentrations in the eastern United States (Shacklette and Boerngen, 1984). This does not demonstrate that there is an ecological problem caused by these inorganics; regional background concentrations were used simply as a screening tool in the absence of soil standards other than proposed RCRA action levels. Soil concentrations detected above eastern United States means were: antimony detected at 3,600 to 13,000 ppb versus a mean of 520 ppb; total chromium at 2,900 to 42,000 ppb versus 33,000 ppb; copper at 760 to 70,800 ppb versus 13,000 ppb; lead at 780 to 138,000 ppb versus 14,000 ppb; nickel at 3,800 to 13,200 ppb versus 11,000 ppb; selenium at 620 to 870 ppb versus 300 ppb; vanadium at 1,600 to 52,200 ppb versus 43,000; and zinc at 6,100 to 257,000 ppb versus 40,000 ppb. Background soil sampling specific to Oceana is needed to determine if these concentrations are above local background concentrations. None of the soil concentrations exceeded proposed RCRA action levels.

The potential effects the above chemicals may have on environmental receptors are discussed in Appendix A.

Fate and Transport

A review of the soil data indicates that there is substantial contamination at the base of the silty unit, which was at or slightly above the water table during the RFI. Contamination was greatest in a 4- to 8-foot zone and generally decreased with depth. It is clear from several borings and from wells 1-MW4 and 1-MW5 that a lens of free product is floating on the water table over a broad area. The existence of contamination in soils below the January 1993 water table suggests that seasonal water-level fluctuations have caused this lens to move up and down through a zone 4 to 8 feet below grade, and that pores in this zone are saturated with free product inches above the prevailing water table and residually saturated at other intervals through which the lens has fluctuated. Most of the constituents of the free-product mixture are not highly mobile.

Groundwater and subsequent surface-water flow are the primary transport mechanisms at Site 1. Groundwater east of the main ditch flows towards the ditch. During the RFI, the ditch acted as a groundwater divide preventing flow across the ditch. During the Interim RFI in 1990, water levels were approximately 2 feet lower, yet surface water was flowing in the main ditch. This suggests that the surface water elevation was higher than the groundwater elevation in the adjacent banks and that groundwater flow was outward from the ditch in contrast to the flow pattern observed during the RFI. The possibility that the stream changes from gaining to losing—both cases in which the ditch acts as a groundwater divide—also suggests that at some times the surface water levels are even with groundwater and may allow groundwater to flow west of the ditch. The absence of contamination in 1-MW7 west of the ditch across from the worst areas of oil contamination suggests that migration west of the ditch is limited.

A salient feature of the ditch contamination is that contamination was observed hundreds of feet upstream of Site 1. Evidence includes reddish clotted material and black oily upwellings from bottom sediments when disturbed. Although Site 1 contamination itself has probably had some effect on the stream quality, much of the contamination appears to originate upstream. The presence of some petroleum constituents in sediment sample 1-SD4 downstream near the radar station shows that some amount of contamination is being transported downstream of Site 1. It is unclear to what degree either upstream sources or Site 1 is the source of the transported contamination.

Small amounts of JP-5 fuel are entering the stream approximately 4,000 feet upstream of Site 1 (Hylton, 1993). This site, which has been under the Virginia underground storage tank (UST) corrective action process since 1988, and is known as the Transmission Line Site, may be the source of the contamination that was detected hundreds of feet upgradient of Site 1.

Recommendations

Although some additional characterization work at Site 1 is recommended, the site data are sufficient to begin the corrective measure study (CMS) of remediations options for soil and groundwater. The pre-CMS data collected during the RFI, which are listed in Appendix H, should allow for some preliminary screening of remedial technologies. CMS activities will include a more complete risk analysis; however, current site data already support a CMS of remediation options.

Because the areas of free product contamination in soils have not been identified completely, additional soil characterization work should be performed at Site 1. The soil sampling program should include several soil borings to determine the soil contamination's northern boundary, and to refine the characterization in other areas. Samples should be analyzed for VOAs and PAHs.

Because there is an ongoing investigation of a UST site upstream of Site 1, sediment data from this investigation should be obtained if available. Additional sediment and surface water sampling upstream of 1-SD3 may be needed to differentiate the contributions of Site 1 and the upstream UST site to contamination in the ditch.

Because natural background concentrations of inorganic constituents in soils at NAS Oceana are unknown, two or more background soil samples from clean areas should be collected to give context to inorganic soil results at Site 1 and several other RFI sites.

Locations of proposed future sampling will be indicated in future work plans subject to review by the EPA and other authorities.

Site 2B—Line Shack 130-131 Disposal Area

Site Location and History

Site 2B is southeast of the main MATWING hangar 122. The site includes Line Shacks 130 through 134, the five aircraft cleaning stations northeast of Line Shack 130 and the meadow and forested area outside the flightline fence.

The IAS states that potential contaminants at Site 2B may include: oil, hydraulic fluid, turco, paint stripper and thinners, PD 680, and aromatic hydrocarbons (naphtha, benzene, toluene and derivatives), all of which were used in aircraft maintenance activities (RGH, 1984). These waste oils and aircraft-maintenance chemicals were disposed of adjacent to the line shacks in unknown amounts beginning in 1963, when the line shacks were constructed, until the early 1980s (RGH, 1984). A hazardous waste collection and recycling program has been in force throughout the base since 1981. During the 1980s an oil-water separator system was installed in the aircraft cleaning area northeast of Line Shack 130 to separate oil from wash water flowing from the aircraft cleaning area.

Past Investigations and RFI Activities

Site 2B has been investigated in three previous studies: (1) the Round 1 Verification Step in 1986, (2) the Line Shack Site Inspection in 1988, and (3) the Interim RFI in 1990. Previous studies indicated that the groundwater is contaminated with chlorinated organics from two or more sources. In addition, minor contamination was identified in samples from the stream adjacent to the site and from the soil locations sampled in 1988.

The purpose of the RFI activities was: (1) to define and separate the sources of groundwater contamination through *in situ* groundwater sampling and the installation and sampling of additional monitoring wells, (2) to focus soil sampling on two probable source areas, and (3) to define the effect of groundwater discharge on the water and sediment in the stream. Because significant shallow contamination has been confirmed, the RFI was also designed to test for the presence of possible deep groundwater contamination in the Yorktown Formation.

The field investigation consisted of:

- Collecting 20 *in situ* groundwater samples in an interactive program of hydraulic probe sampling (2B-GP1 through 2B-GP20)
- Installing two deep (2B-MW1D, 2B-MW5D) and 5 shallow monitoring wells (2B-MW12 through 2B-MW16)
- Sampling all new and existing monitoring wells

- Collecting and analyzing soil samples from multiple depths at two potential source areas (2B-SB1 through 2B-SB7)

- Sampling sediments and surface water in the perennial stream adjacent to the site.

All hydraulic probe samples were collected from 9 to 12 feet except samples from 2B-GP8 and 2B-GP13, which were collected from 15 to 18 feet. The Site 2B monitoring well system is summarized in Table 4-2-1.

Because previous broad-spectrum sampling had identified only chlorinated VOCs and some TPH in the stream, the groundwater and soil samples were analyzed for chlorinated VOCs, and the sediment and surface water in the stream were analyzed for chlorinated VOCs and TPH. The locations of all samples collected at Site 2B during the RFI are shown on Figure 4-2-1.

Environmental Setting

Figure 4-2-2 is an ecological map of Site 2B, 2C, 2D, 2E, 18, and 26. The Site 2B study area is approximately 14 acres. This area was traversed on foot and by vehicle during the onsite study.

Much of the ground surface in the immediate area of Line Shack 130 and 131 is covered with concrete or asphalt. A fence surrounds the impervious surfaces and separates the developed portion of the study site from the undeveloped portion. Except for the forested area and open field, most of the site is within the flightline. The flat terrain is interrupted only by drainage ditches and a few berms left from previous disturbances. The soils in the undeveloped areas are mostly made up of sandy silt material underlain by silty clay or sandy loam.

Ecology

Surface Water Resources. Drains within the aircraft cleaning area of Site 2B direct runoff to oil-water separators before discharge to sanitary sewers. Off the flight line, two drainage ditches direct surface flow from the site. These ditches flow to the southeast. The ditches had approximately 3 to 8 inches of water at the time of the onsite survey. No submerged aquatic vegetation was observed in the ditches. Fairly high levels of turbidity was observed in both ditches. A reddish-brown material, much like that at Sites 1 and 11, occurs at various thicknesses throughout the length of the ditches. The material in the ditches was thickest close to the developed portion of the site.

Wetlands. Much of the open field is a wetland area. Most soils in this area were saturated to the surface at the time of the onsite survey. The forested area had some small pockets of saturated soils. The soils in the undeveloped areas are composed mostly of

Table 4-2-1
SITE 2B MONITORING WELL SUMMARY

Well Number	Date Installed	Ground Elevation (feet above MSL)	Total Depth (feet)	Screened Interval (feet below ground surface)
2B-MW1	04/03/86	21.8	19	9-19
2B-MW1D	12/08/92	21.73	46	36-46
2B-MW2	04/01/86	18.0	25	15-25
2B-MW3	04/02/86	18.8	20	10-20
2B-MW4	09/02/88	21.5	19	9-19
2B-MW5	09/01/88	22.0	18	8-18
2B-MW5D	12/10/92	21.80	47	37-47
2B-MW6	09/06/88	21.5	15	5-15
2B-MW7	06/27/90	18.7	14	9-14
2B-MW8	06/29/90	18.0	20	10-20
2B-MW9	06/29/90	20.5	20	10-20
2B-MW10	07/11/90	22.1	18	8-18
2B-MW11	07/10/90	22.1	18	8-18
2B-MW12	12/04/92	18.4	22.5	12.5-22.5
2B-MW13	12/04/92	17.9	20.0	10-20
2B-MW14	12/04/92	17.4	20.0	10-20
2B-MW15	12/04/92	19.0	22.5	12-22
2B-MW16	01/12/93	21.16	20.0	10-20

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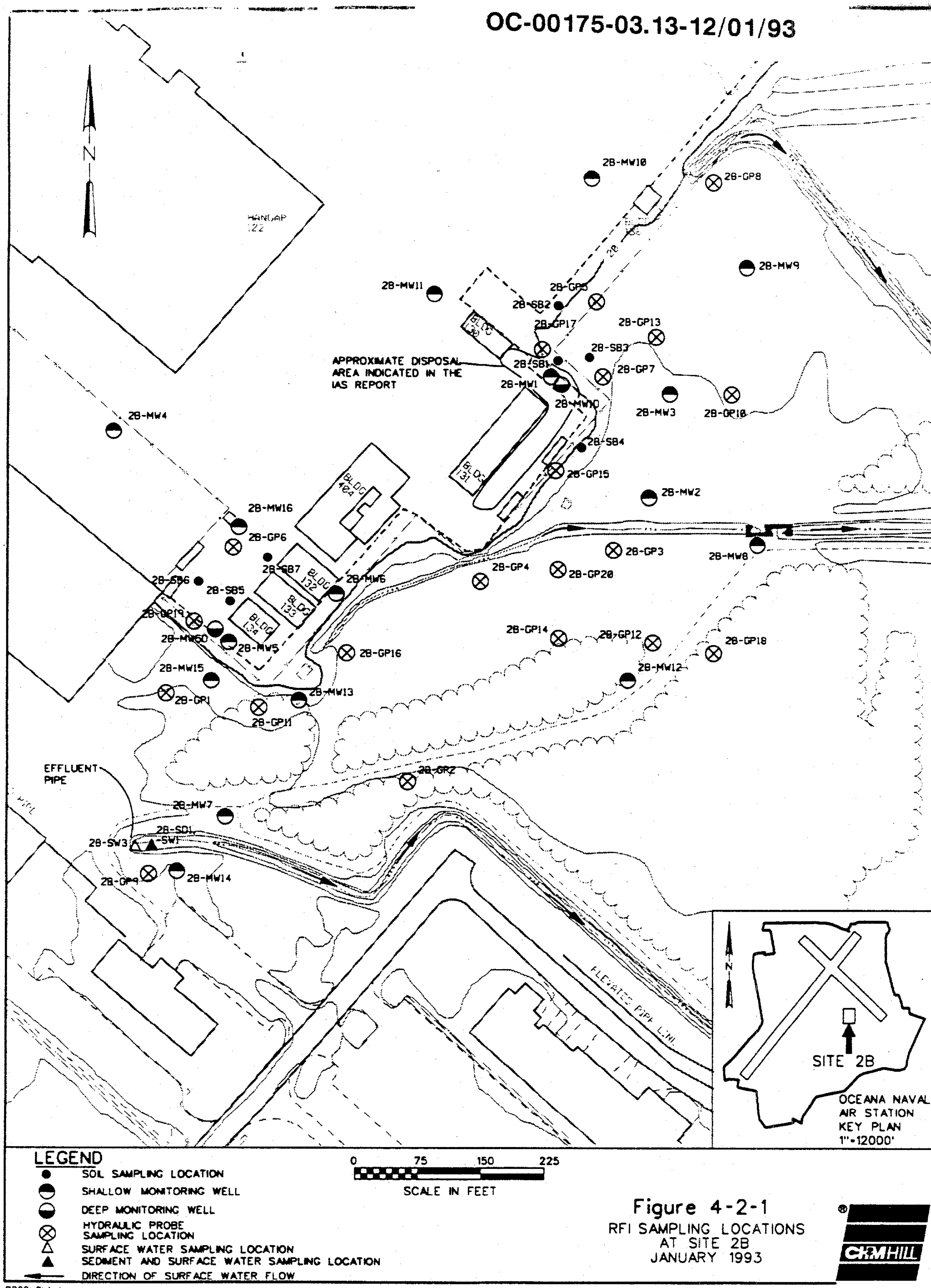

Figure 4-2-1
RFI SAMPLING LOCATIONS
AT SITE 2B
JANUARY 1993

CH2M HILL

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sandy silt material and silty clay or sandy loam. The soil series is Acredale-Tomotley, which is classified as hydric; however, most of the forested area near Site 2B is apparently not a wetland. A series of small, shallow ditches were observed throughout the forested area. The hydric classification for the soils in this area may be based on conditions before the area was drained. No evidence of contamination in the wetlands was observed during the site visit.

Vegetation. The vegetation in the open field is dominated by early successional species common to previously disturbed wetland areas. The dominant vegetation in the open field area includes panic grass, plume grass, and bluestem grass. Other species observed were sweetgum, blackberry, giant cane, goldenrod, and paspalum grass. Wool grass and soft rush were observed near the ditch edges in the open field. Vegetation stress was not observed in the open field.

Except for the cleared horsetrails, the vegetation in the forested area appears relatively undisturbed. Loblolly pine, sweetgum, and American beech dominate the overstory. Black cherry, giant cane, paw paw, waxmyrtle, and southern red oak also occur in large numbers. No signs of vegetation stress was observed in the forested area. Figure 4-2-2 is an ecological map of Site 2B.

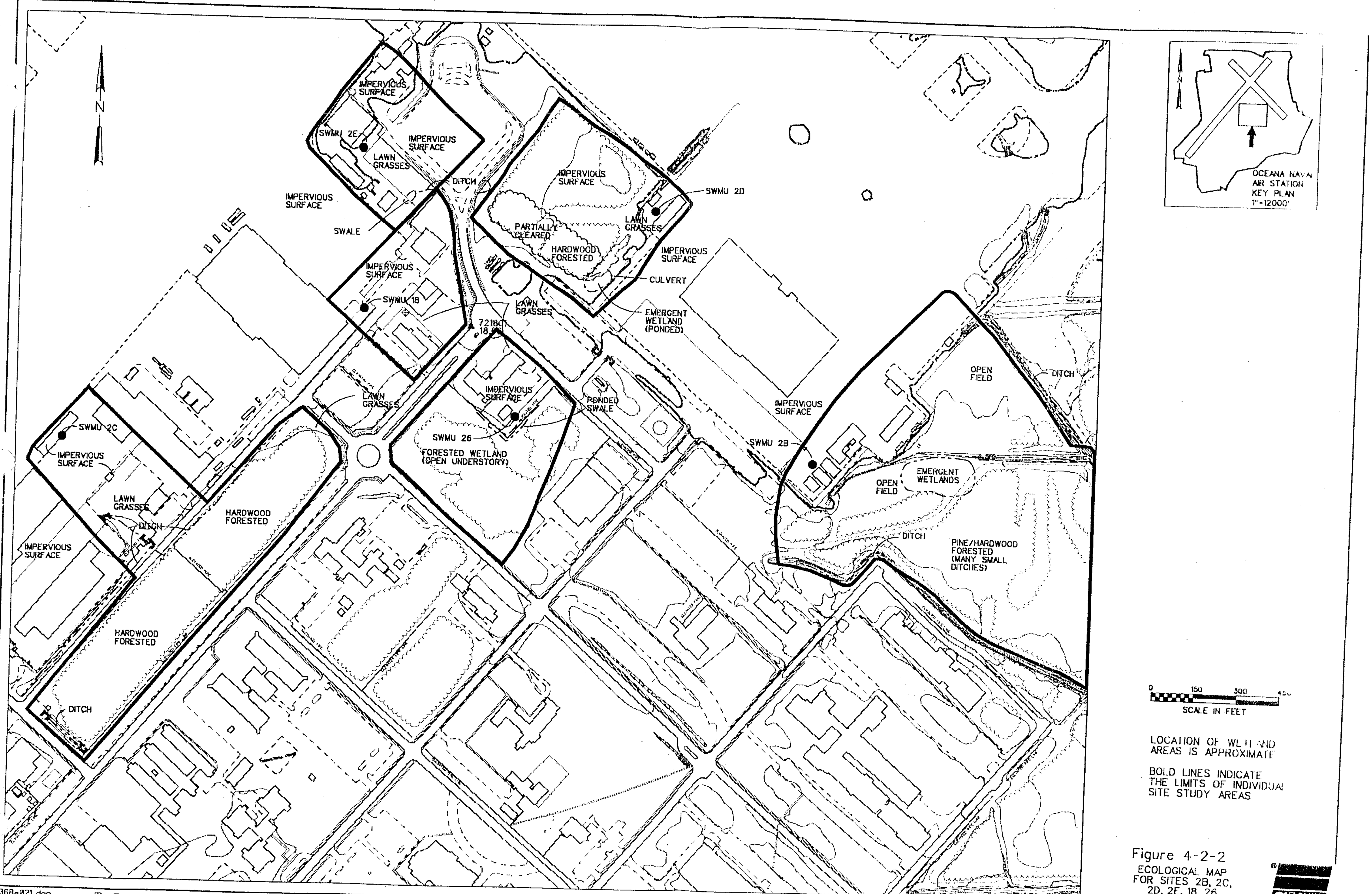
Wildlife. Quail and many yellow-rumped warblers were among the only wildlife observed during the site visit. Signs that a large population of deer exists in this area were observed, including trails, scat, and hoof prints. Other mammal signs observed were raccoon tracks, squirrel nests, and possibly groundhog dens.

Geologic and Hydrogeologic Characteristics

As shown by boreholes drilled during this RFI, the subsurface geology consists of three stratigraphic units. The uppermost unit is a 7- to 10-foot-thick unit of fine sediments, mainly silty clays and sandy silts. This is underlain by a 5- to 10-foot-thick layer of clean, fine to medium sand. These two units correspond to the Columbia Group sediments described in Chapter 2. The clean sand is underlain by a silty sand interlayered with zones of cleaner sand to a depth of 55 feet. Shells and shell hash indicative of the top of the Yorktown Formation were typically encountered at approximately 25 feet. The two new deep wells penetrated the Yorktown Formation approximately 30 feet.

The water levels measured at Site 2B on February 24, 1993, are listed in Table 4-2-2 and illustrated in Figure 4-2-3. Figure 4-2-3 shows the estimated equipotential contour lines in the shallow Columbia Group sand and lists the deep-well water elevations. Water levels were higher than past measurements because of abundant rain in December and early January. Deep water-level data are not contoured because of insufficient data.

The data show that shallow groundwater within the Columbia Group sand flows is a southwest to southeast arc away from the flightline area toward the perennially flowing



LOCATION OF WETLAND AREAS IS APPROXIMATE

BOLD LINES INDICATE THE LIMITS OF INDIVIDUAL SITE STUDY AREAS

Figure 4-2-2
ECOLOGICAL MAP FOR SITES 2B, 2C, 2D, 2E, 18, 26
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THIS FIGURE WAS BASED ON A 1986 AIR PHOTOGRAPH AND DOES NOT INDICATE 1993 CONDITIONS NEAR SITES 2C AND 2D.

Table 4-2-2
SITE 2B WATER-LEVEL DATA
February 24, 1993

Well	Depth to Water (Feet Below Survey Datum)	Water-Level Elevation (Feet Above Mean Sea Level)
2B-MW1	6.83	14.76
2B-MW1D	7.12	14.61
2B-MW2	5.84	14.50
2B-MW3	4.65	14.58
2B-MW4	6.51	14.42
2B-MW5	7.13	14.36
2B-MW5D	7.38	14.42
2B-MW6	6.45	14.56
2B-MW7	7.08	13.87
2B-MW8	5.55	14.47
2B-MW9	7.65	14.62
2B-MW10	7.65	14.42
2B-MW11	7.28	14.79
2B-MW12	6.9	14.39
2B-MW13	5.96	14.44
2B-MW14	6.28	14.13
2B-MW15	7.58	14.39
2B-MW16	6.50	14.66
Surface water in ditch near 2B-MW7	Approximately 6 inches above sediment surface surveyed at 13.2 feet	13.7 (estimated)

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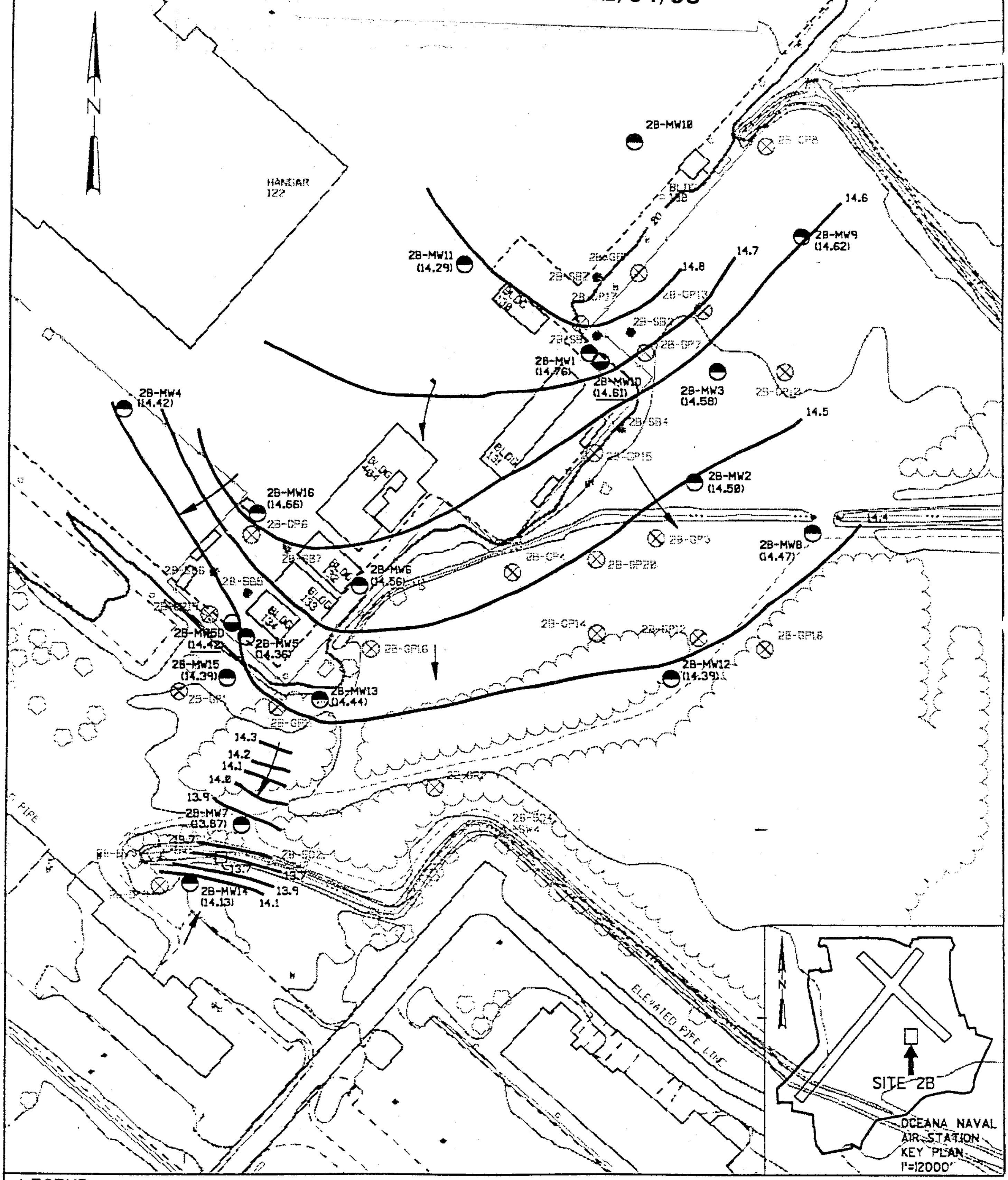

LEGEND

- SOIL SAMPLING LOCATION
- SHALLOW MONITORING WELL
- DEEP MONITORING WELL
- ELEVATION OF WATER IN DITCH
- HYDRAULIC PROBE SAMPLING LOCATION
- DIRECTION OF GROUNDWATER FLOW
- ( ) WATER LEVEL ELEVATIONS OF COLUMBIA AQUIFER
- ( ) WATER LEVEL IN YORKTOWN FORMATION

0 75 150 225

SCALE IN FEET

Figure 4-2-3

WATER LEVELS WITH EQUIPOTENTIAL CONTOURS FOR THE COLUMBIA AQUIFER AT SITE 2B FEBRUARY 24, 1993

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ditch. Flow is to the southeast over most of the area from Line Shacks 138 to 134, but it is to the southwest northwest of Line Shacks 132, 133, and 134. This pattern is generally consistent with past investigations.

The estimated elevation of the water level within the main ditch adjacent to the site is shown in Figure 4-2-3 as 13.7 feet. The water level in the ditch is approximately 0.17 feet below the water level in well 2B-MW7 and 0.43 feet below the water level in 2B-MW14. Because the groundwater system and the ditch system are linked, these data clearly show that groundwater from the site was discharging to the ditch from both the north and south sides during the RFI.

The horizontal groundwater gradients vary with location. The gradients were approximately 0.001 ft/ft from 2B-MW1 to 2B-MW2, 0.0005 ft/ft from 2B-MW3 to 2B-MW8, and 0.003 ft/ft near 2B-MW16. The water-level measurements in the two shallow/deep well pairs indicate that the vertical groundwater gradient is very low at the two well pairs. The gradient was slightly downward (-0.006) at 2B-MW1/2B-MW1D and slightly upward (+0.002) at 2B-MW5/2B-MW5D.

Contamination and Extent

In Situ Groundwater Sampling

Table 4-2-3 lists the analytical results of the *in situ* groundwater sampling conducted by using the hydraulic probe. The samples were analyzed on the site for 11 volatiles and total petroleum volatiles (TPV) by using the mobile laboratory. The results of the confirmatory sample splits sent to CH2M HILL's laboratory in Gainesville, Florida, also are listed. A discussion of the results of the 8010 chlorinated volatiles analysis of groundwater in the monitoring wells is included in the next section.

The distribution of total target chlorinated volatiles in the *in situ* groundwater samples is shown in Figure 4-2-4. The *in situ* data indicate that the groundwater is contaminated with chlorinated hydrocarbons in one area near Line Shack 134 and in another area near Line Shack 131. Some amount of fuel-related BTEX contamination was also detected in the groundwater at locations 2B-GP17 and 2B-GP5 east of Line Shack 130.

The concentrations shown in Figure 4-2-4 are only for the seven chlorinated VOCs analyzed by the mobile laboratory and do not show BTEX compounds. However, because the seven chlorinated hydrocarbons include the key chlorinated VOC constituents detected in past studies, the screening data shown in Figure 4-2-4 are generally representative of VOC contamination in these areas.

The primary contaminants detected were trichloroethylene (TCE), cis- and trans-1,2-dichloroethylene (1,2-DCE), vinyl chloride, 1,1-dichloroethylene (1,1-DCE), and

Table 4-2-3
ORGANIC COMPOUNDS IN GROUNDWATER AT SITE 2B
RESULTS FROM *IN SITU* GROUNDWATER SAMPLES
November 1992
(All data in $\mu g/l$)

Analyte	2B-GP1	2B-GP2	2B-GP3	2B-GP4	2B-GP5	2B-GP6	2B-GP7	2B-GP8	2B-GP9	2B-GP10	2B-GP11
Volatile Organic Compounds											
Vinyl Chloride	*	*	2.7	2.1	3.6	2.3	*	*	*	*	*
1,1-Dichloroethylene	*	*	*	*	*	*	*	*	*	*	*
trans-1,2-Dichloroethylene	*	*	*	*	2.7	6.4	*	*	*	*	*
1,1-Dichloroethane	*	*	*	*	4.1	3.6	3.6	*	*	*	*
cis-1,2-Dichloroethylene	*	*	*	*	4.7	*	3.6	*	*	*	*
1,1,1-Trichloroethane	*	*	110	*	*	*	*	*	*	*	*
Trichloroethylene	*	*	*	*	10	*	13	*	*	5.0	*
Benzene	*	*	*	*	*	*	*	*	*	*	*
Toluene	*	*	*	*	*	*	*	*	*	*	*
Ethylbenzene	*	*	*	*	59	*	*	*	*	*	*
Total Xylenes	*	*	*	*	*	*	*	*	*	*	*
Total Petroleum Volatiles	*	*	*	*	980	*	*	*	*	*	*

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Table 2-3
ORGANIC COMPOUNDS IN GROUNDWATER AT SITE 2B
RESULTS FROM *IN SITU* GROUNDWATER SAMPLES
November 1992
(All data in $\mu g/l$)

Analyte	2B-GP12	2B-GP13[b]	2B-GP14	2B-GP15		2B-GP16	2B-GP17		2B-GP18	2B-GP19	2B-GP20
				Field GC	Standard Lab GC[a]		Field GC	Standard Lab GC[a,b]			
Volatile Organic Compounds											
Vinyl Chloride	*	*	*	5.6	130	*	*	*	*	92	21
1,1-Dichloroethylene	*	*	*	310	*	*	*	*	*	*	*
trans-1,2-Dichloroethylene	*	*	*	56	100	*	*	*	*	*	*
1,1-Dichloroethane	*	*	*	*	*	*	26	7.3	*	*	*
cis-1,2-Dichloroethylene	*	*	*	120	1,300	*	4.4	19	*	*	5.8
1,1,1-Trichloroethane	*	*	*	*	*	*	*	*	*	*	*
Trichloroethylene	11	0.7	*	140	1,000	1.3	13	5.9	2.0	*	19
Benzene	*	*	*	*	NA	*	33	NA	*	*	*
Toluene	*	*	*	*	NA	*	18	NA	*	*	*
Ethylbenzene	*	*	*	*	NA	*	45	NA	*	*	*
Total Xylenes	*	*	*	*	NA	*	67	NA	*	*	*
Total Petroleum Volatiles	*	*	*	*	NA	*	5,400	NA	*	*	*

Notes:

All volatile organic compounds not reported were below detection limits in all samples.
[a]During the data validation process, all positive VOC results were qualified as tentatively identified because the results were not confirmed by second column analyses.
[b]The data validation process qualified the VOC detects as estimated and rejected the non-detects because the sample containers had headspace.
NA - Not analyzed
*The value was less than the IDL or was not detected
QC Sampling - The duplicates for 2B-GP15 and 2B-GP17 were submitted to the CH2M HILL Analytical Laboratory in Montgomery, Alabama

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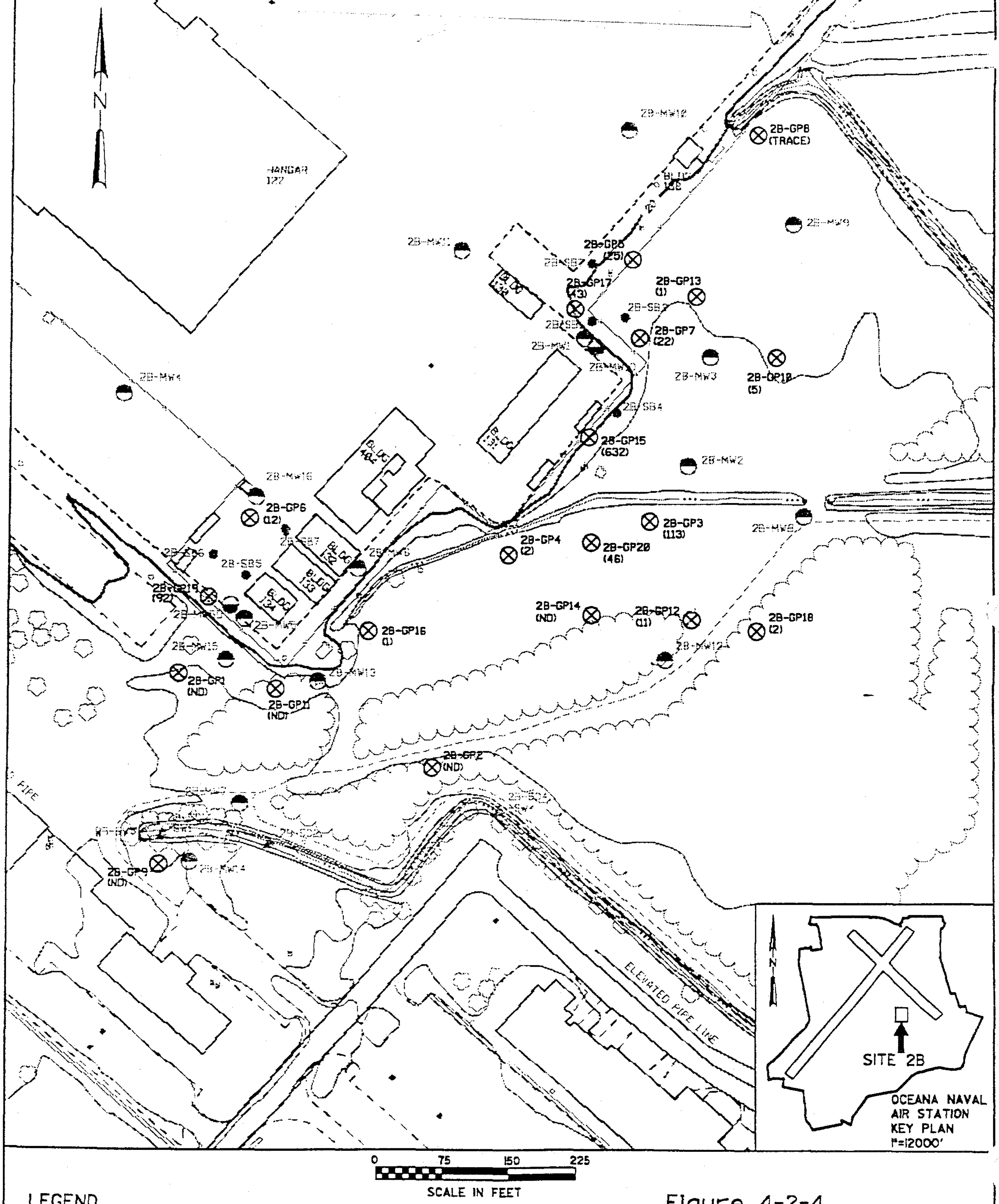

LEGEND

- SOIL SAMPLING LOCATION
- SHALLOW MONITORING WELL
- DEEP MONITORING WELL
- HYDRAULIC PROBE SAMPLING LOCATION
- ( ) TOTAL CONCENTRATION OF 7 TARGET CHLORINATED VOLATILES IN ppb
- ND NOT DETECTED

Figure 4-2-4
TOTAL TARGET CHLORINATED VOLATILES IN IN-SITU GROUNDWATER SAMPLES AT SITE 2B

CH2M HILL

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1,1-dichloroethane (1,1-DCA). These constituents are all common degreaser solvents or their associated breakdown products and are probably related to the aircraft cleaning and maintenance activities at this site.

The highest concentration of total VOCs was observed in 2B-GP15 southeast of Line Shack 131. The groundwater contamination in this area may be caused by chemical releases through the fenceline near the northeast corner of the line shack. A history of waste disposal in this area is known. Waste petroleum products were observed on the soil surface during the 1986 study. This visible contamination was removed and follow-up soil sampling in this area did not show contamination (CH2M HILL, 1988). However, persistent releases in this area appear to have contaminated the groundwater with chlorinated VOCs.

A vinyl chloride concentration of 92 ppb was detected in 2B-GP19 in the western source area. Further confirmation of vinyl chloride contamination in groundwater in this area was indicated by monitoring well data presented below.

Benzene, toluene, ethylbenzene, and total xylenes were also detected in 2B-GP17 and ethylbenzene was detected in 2B-GP5. In addition, TPV concentrations analyzed by the mobile laboratory were 5,400 ppb in 2B-GP17 and 980 ppb in 2B-GP5. These four individual aromatic volatile organics are fuel constituents and TPV is a summation of fuel-related volatiles. Both types of data suggest that fuels were spilled in or upslope of the grassy area east of Line Shack 130, possibly in the aircraft cleaning area.

Monitoring Well Data

The results from monitoring well sampling confirmed the results of the *in situ* groundwater sampling data. Of the 30 compounds on the chlorinated volatile list, 7 were detected in groundwater from monitoring wells at Site 2B. Of these, only four compounds are widely distributed: TCE, vinyl chloride, 1,2-DCE, and 1,1-DCA.

The well data are listed in Table 4-2-4 and are illustrated in Figure 4-2-5. Figure 4-2-5 shows that both the eastern and western plumes consist of all four of these compounds, each with somewhat different distributions. The composition of the chlorinated volatile contamination is different in different areas. The contamination near Line Shack 134 is primarily vinyl chloride with low concentrations of 1,1-DCA and trans-1,2-DCE. The contamination southeast of Line Shack 131 is primarily TCE, 1,1-DCE, and 1,2-DCE, with low concentrations of vinyl chloride, and the contamination east and southeast of Line Shack 130 is primarily TCE with 1,1-DCA and 1,2-DCE. These differences may indicate that the releases from each area had a different history and composition; however, these variations are not likely to have an effect on the remedial action at the site.

Eastern Source Area. The contaminant plume in the eastern source area was centered near 2B-MW1 and bounded by 2B-MW9 (total VOCs of 7 ppb) and 2B-MW10 (non-detect)

Table 4-2-4
ORGANIC COMPOUNDS IN GROUNDWATER AT SITE 2B
RESULTS OF RFI AND PREVIOUS STUDIES
(All concentrations in μg/l)

Analyte	Detection Limit	2B-MW1						2B-MW1D	2B-MW2			
		May 86	Sept. 88		Aug. 90		Jan. 93	Jan. 93	May 86	Sept. 88	Aug. 90	Jan. 93
			Initial	Duplicate	Initial	Duplicate						
EDB	0.02	*	NA	NA	*	*	NA	NA	*	NA	*	NA
Oil and Grease	3,000	3,000	NA	NA	NA	NA	NA	NA	5,000	NA	NA	NA
TPH	60	NA	NA	NA	220	210	NA	NA	NA	NA	110	NA
Volatile Organic Compounds[a]												
Acetone	10	*	*	*	22 bj	24 bj	NA	NA	*	*	5 bj	NA
Benzene	5	*	*	*	*	*	NA	NA	*	*	*	NA
2-Butanone (MEK)	10	*	*	*	*	*	NA	NA	*	*	*	NA
Carbon Disulfide	5	*	*	*	*	*	NA	NA	*	*	*	NA
Chloroethane	1,10	20	*	*	*	*	*	*	*	*	*	*
Chloroform	1,5	*	*	*	*	*	*	*	2.8	*	*	*
1,1-Dichloroethane	1,5	170	82	52	50	49	25	*	*	*	*	*
1,2-Dichloroethane	1,5	*	*	*	*	*	*	*	*	*	*	*
1,1-Dichloroethylene	1,5	25	13	6	10 j	11 j	*	*	*	*	*	*
1,2-Dichloroethylene (Total)	5	NA	340	290	400	400	NA	NA	NA	*	5	NA
Cis-1,2-Dichloroethylene	1	NA	NA	NA	NA	NA	320	*	NA	NA	NA	5.3
Trans-1,2-Dichloroethylene	1,5	800	NA	NA	NA	NA	*	*	*	NA	NA	*
2-Hexanone	10	*	*	*	*	*	NA	NA	*	*	*	NA
4-Methyl-2-Pentanone (MIBK)	10	*	*	*	*	*	NA	NA	*	*	*	NA
Methylene Chloride	1,5	*	*	*	6 bj	7 bj	*	*	*	*	5 b	*
1,1,2,2-Tetrachloroethane	1,5	*	*	*	*	*	*	*	*	*	*	*
Toluene	5	*	*	*	*	*	NA	NA	*	*	*	NA
Trichloroethylene	1,5	1,300	330	340	230	280	250	*	3.7	5	7	7.4
Vinyl Chloride	1,10	99	31	27	30	37	*	*	*	*	*	*
Semivolatile Compounds[a]	10,50	NA	NA	NA	NA	NA	*	NA	NA	NA	NA	NA

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Table 4-2-4
ORGANIC COMPOUNDS IN GROUNDWATER AT SITE 2B
RESULTS OF RFI AND PREVIOUS STUDIES
(All concentrations in $\mu g/l$)

Analyte	2B-MW3				2B-MW4			2B-MW5				2B-MW
	May 86	Sept. 88	Aug. 90	Jan. 93	Sept. 88	Aug. 90	Jan. 93	Sept. 88	Aug. 90	Jan. 93 Initial	Jan. 93 Duplicate	Jan. 9
EDB	*	NA	*	NA	NA	*	NA	NA	*	NA	NA	NA
Oil and Grease	5,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TPH	NA	NA	70	NA	NA	390	NA	NA	200	NA	NA	NA
Volatile Organic Compounds*												
Acetone	*	*	35 b	NA	*	6 bj	NA	*	6 bj	NA	NA	NA
Benzene	*	*	*	NA	*	*	NA	*	1 j	NA	NA	NA
2-Butanone (MEK)	21	*	*	NA	*	*	NA	*	*	NA	NA	NA
Carbon Disulfide	*	*	*	NA	*	3 j	NA	*	*	NA	NA	NA
Chloroethane	*	*	*	*	*	*	*	*	*	*	*	*
Chloroform	*	*	*	*	*	*	*	*	*	*	*	*
1,1-Dichloroethane	3.2	44	18	16	*	*	*	7	12	10	10	*
1,2-Dichloroethane	*	*	*	*	*	*	*	*	*	*	*	*
1,1-Dichloroethylene	*	420	*	*	*	*	*	49	4 j	1.9	1.6	*
1,2-Dichloroethylene (Total)	NA	*	140	NA	*	*	NA	*	6	NA	NA	NA
Cis-1,2-Dichloroethylene	NA	NA	NA	180	NA	NA	*	NA	NA	22	22	*
Trans-1,2-Dichloroethylene	29	NA	NA	*	NA	NA	*	NA	NA	*	*	*
2-Hexanone	9.1	*	*	NA	*	*	NA	*	*	NA	NA	NA
4-Methyl-2-Pentanone (MIBK)	6.6	*	*	NA	*	*	NA	*	*	NA	NA	NA
Methylene Chloride	*	*	10 b	*	*	5 b	*	*	5 b	*	*	*
1,1,2,2-Tetrachloroethane	2.4	*	*	*	*	*	*	*	*	*	*	*
Toluene	3.4	*	*	NA	*	*	NA	*	*	NA	NA	NA
Trichloroethylene	58	820	230	240	*	*	*	22	3 j	*	*	*
Vinyl Chloride	3.0	*	*	*	*	*	*	55	*	*	1.2	*
Semivolatile Compounds*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

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Table 4-2-4
ORGANIC COMPOUNDS IN GROUNDWATER AT SITE 2B
RESULTS OF RFI AND PREVIOUS STUDIES
(All concentrations in $\mu g/l$)

Analyte	Detection Limit	2B-MW6			2B-MW7			2B-MW8		2B-MW9	
		Sept. 88	Aug. 90	Jan. 93	Aug. 90	Jan. 93		Aug. 90	Jan. 93	Aug. 90	Jan. 93
						Initial	Duplicate				
EDB	0.02	NA	*	NA	*	NA	NA	*	NA	*	NA
Oil and Grease	3,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TPH	60	NA	290	NA	ND	NA	NA	130	NA	300	NA
Volatile Organic Compounds*											
Acetone	10	*	8 bj	NA	14 b	NA	NA	26 b	NA	5 bj	NA
Benzene	5	*	*	NA	2 j	NA	NA	*	NA	*	NA
2-Butanone (MEK)	10	*	*	NA	*	NA	NA	*	NA	*	NA
Carbon Disulfide	5	*	*	NA	*	NA	NA	*	NA	*	NA
Chloroethane	1,10	*	*	*	4 j	*	*	*	*	*	*
Chloroform	1,5	*	*	*	*	*	*	*	*	*	*
1,1-Dichloroethane	1,5	*	*	*	110	19	20	*	*	*	*
1,2-Dichloroethane	1,5	*	*	*	3 j	*	*	*	*	*	*
1,1-Dichloroethylene	1,5	*	*	*	4 j	2.0	2.5	*	*	*	*
1,2-Dichloroethylene (Total)	5	*	3	NA	40	NA	NA	*	NA	*	NA
Cis-1,2-Dichloroethylene	1	NA	NA	*	NA	14	14	NA	*	NA	3.3
Trans-1,2-Dichloroethylene	1,5	NA	NA	*	NA	*	*	NA	*	NA	*
2-Hexanone (MBK)	10	*	*	NA	*	NA	NA	*	NA	*	NA
4-Methyl-2-Pentanone (MIBK)	10	*	*	NA	27	NA	NA	*	NA	*	NA
Methylene Chloride	1,5	*	5 b	*	4 bj	*	*	8 bj	*	5 bj	*
1,1,2,2-Tetrachloroethane	1,5	*	*	*	*	*	*	*	*	*	*
Toluene	5	*	*	NA	1 j	NA	NA	*	NA	*	NA
Trichloroethylene	1,5	*	*	*	18	12	12	*	*	2 j	4.2
Vinyl Chloride	10	*	22	3.8	58	8.3	7.5	*	*	*	*
Semivolatile Compounds*	10,50	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

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Table 4-2-4
ORGANIC COMPOUNDS IN GROUNDWATER AT SITE 2B
RESULTS OF RFI AND PREVIOUS STUDIES
(All concentrations in $\mu g/l$)

Analyte	2B-MW10		2B-MW11		2B-MW12	2B-MW13	2B-MW14	2B-MW15	2B-MW16
	Aug. 90	Jan. 93	Aug. 90	Jan. 93	Jan. 93	Jan. 93	Jan. 93	Jan. 93	Jan. 93
EDB	*	NA	*	NA	NA	NA	NA	NA	NA
Oil and Grease	NA	NA	NA	NA	NA	NA	NA	NA	NA
TPH	140	NA	240	NA	NA	NA	NA	NA	NA
Volatile Organic Compounds*									
Acetone	5 bj	NA	6 bj	NA	NA	NA	NA	NA	NA
Benzene	1 j	NA	*	NA	NA	NA	NA	NA	NA
2-Butanone (MEK)	*	NA	*	NA	NA	NA	NA	NA	NA
Carbon Disulfide	*	NA	*	NA	NA	NA	NA	NA	NA
Chloroethane	*	*	*	*	*	*	*	34	*
Chloroform	*	*	*	*	*	*	*	*	*
1,1-Dichloroethane	16	*	*	3.7	*	*	*	92	3.5
1,2-Dichloroethane	*	*	*	*	*	*	25	1.4	*
1,1-Dichloroethylene	2 j	*	*	*	*	*	*	2.5	*
1,2-Dichloroethylene (total)	24	NA	*	NA	NA	NA	NA	NA	NA
Cis-1,2-Dichloroethylene	NA	*	NA	*	*	*	*	8.1	6.4
Trans-1,2-Dichloroethylene	NA	*	NA	*	*	*	*	*	*
2-Hexanone (MBK)	*	NA	*	NA	NA	NA	NA	NA	NA
4-Methyl-2-Pentanone (MIBK)	*	NA	*	NA	NA	NA	NA	NA	NA
Methylene Chloride	3 bj	*	4 bj	*	*	1.2	*	*	*
1,1,2,2-Tetrachloroethane	*	NA	*	*	*	*	*	*	*
Toluene	*	NA	*	NA	NA	NA	NA	NA	NA
Trichloroethylene	*	*	*	*	*	*	*	3.0	*
Vinyl Chloride	*	*	*	*	*	*	3.2	21	6.4
Semivolatile Compounds*	NA	NA	NA	NA	NA	NA	NA	NA	NA

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Table 4-2-4
ORGANIC COMPOUNDS IN GROUNDWATER AT SITE 2B
RESULTS OF RFI AND PREVIOUS STUDIES
(All concentrations in μg/l)

Notes:

*All volatile and semivolatile compounds not listed in the table above were analyzed for but were below the detection limit in all samples.
EDB - Ethylene Dibromide.
NA - Not Analyzed.
ND - No data.
TPH - Total Petroleum Hydrocarbon.
b Compound found in laboratory blank as well as sample. Sample concentration is less than 10 times blank concentration.
j Estimated value. Measured value is less than the accurately quantitative detection limits.
* Not detected.

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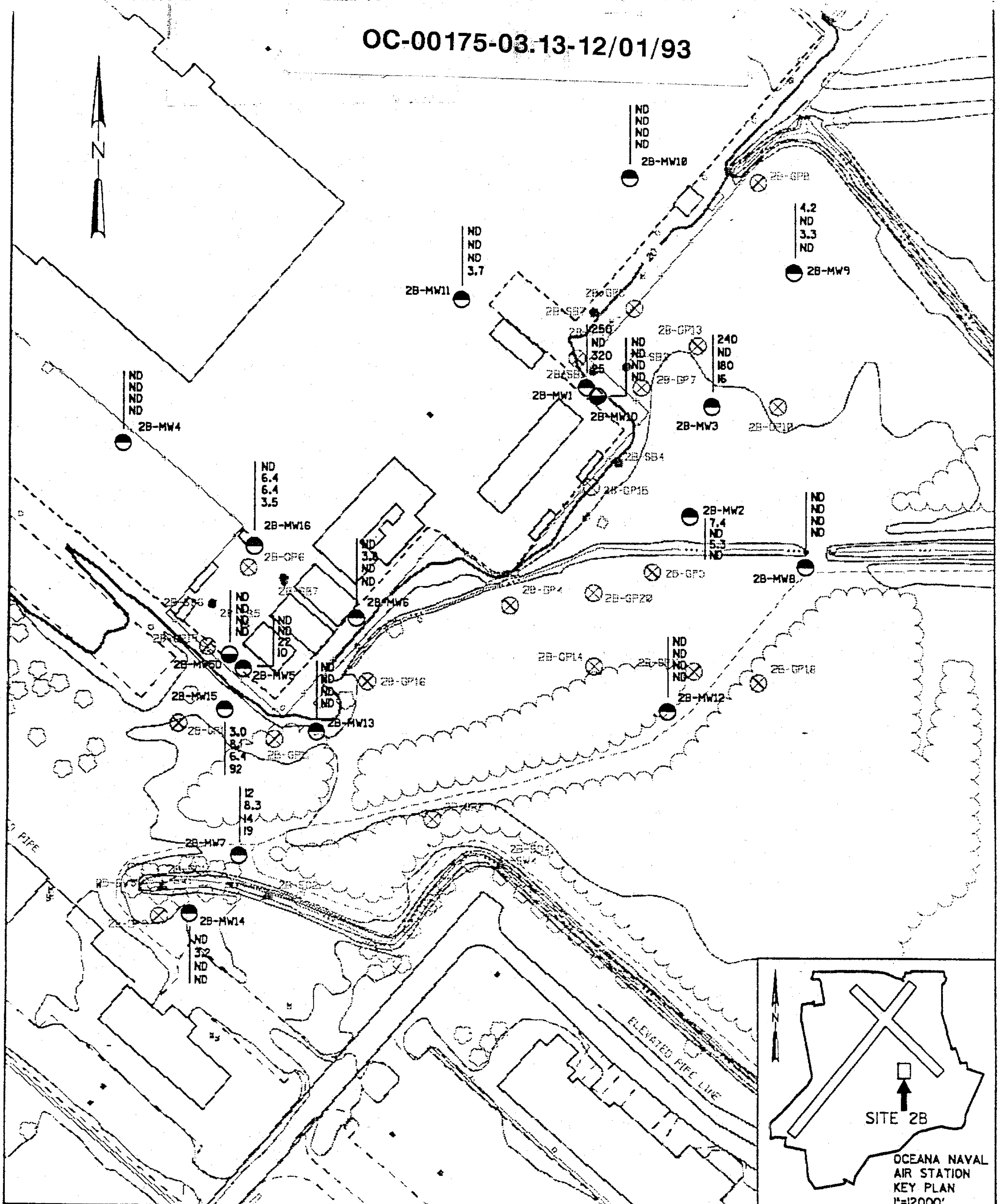

LEGEND

- SOIL SAMPLING LOCATION
- SHALLOW MONITORING WELL
- DEEP MONITORING WELL
- HYDRAULIC PROBE SAMPLING LOCATION

CONCENTRATIONS IN ppb
TCE
VINYL CHLORIDE
1,2 - DCE
1,1 - DCA

0 75 150 225
SCALE IN FEET

Figure 4-2-5
VOLATILE ORGANICS IN MONITORING WELLS AT SITE 2B
JANUARY, 1993

CH2M HILL

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6-Apr-1993

on the north and east; 2B-MW8 (non-detect) and 2B-MW12 (non-detect) on the south; and 2B-MW11 (4 ppb) and 2B-GP4 (2 ppb) on the west. However, the *in situ* groundwater data indicate that total volatile contamination extends to 2B-GP8 on the north, 2B-GP10 (5 ppb) on the east, 2B-GP20 (11 ppb) on the west, and 2B-GP18 (2 ppb) on the south, and is, therefore, slightly more extensive than indicated by monitoring well results alone. The plume is bounded by non-detects on the north and west and is present at very low levels in screening samples on the east and south. In general, the extent of volatile contamination in the eastern plume has been defined to low levels by existing groundwater sampling.

Western Source Area. The western plume appears to be centered around the concrete area northwest of Line Shacks 132, 133, and 134. Both wells and *in situ* sampling locations in this area were found to be contaminated with TCE, 1,2-DCE, 1,1-DCA, and vinyl chloride. The total VOC plume is bounded on the west by the non-detect in 2B-MW4 and on the east by the non-detect in 2B-MW13, and the 4 ppb total VOCs in 2B-MW6. A total of 56 ppb of chlorinated VOCs were detected in well 2B-MW7 near the ditch at concentrations of from 2 to 19 ppb. It is unclear whether the plume is continuous from the line shacks to this well because *in situ* samples 2B-GP11 and 2B-GP1 did not contain any volatiles. The plume is possibly continuous but is deeper than the 9 to 12 foot sampling depth of the *in situ* hydraulic probe sampling.

It is significant that contamination was detected in well 2B-MW14 on the south side of the ditch. Vinyl chloride (3.2 ppb) and 1,2-dichloroethane (25 ppb) were detected in this well. As mentioned above, the horizontal gradients observed in January and February 1993 were towards the ditch from both the north and south banks. However, a review of water level data from the interim RFI shows that the water level in well 2B-MW7 in October 1990 was 12.22 feet, or 1.65 feet lower than in February 1993. The elevation of water in the ditch was not measured then but was probably not less than 13.5 feet based on observations of the ditch during both investigations. This suggests that the ditch can be either a gaining or losing stream or be even with prevailing groundwater levels depending on seasonal water level fluctuation. As a result, for some part of the year the main ditch may possibly not be an effective groundwater divide preventing groundwater flow south across the ditch.

No contamination was detected in deep wells 2B-MW1D and 2C-MW5D. The lack of deep contamination in the two source areas is probably caused by the low vertical driving force and the low permeability of the silty sands and silts between the shallow and deep screened zones.

Soils

No chlorinated volatile organics were detected in the seven soil samples collected from borings advanced to the water table. Data on OVA readings during soil sampling at 2B are included in Appendix C.

Sediment and Surface Water

The analytical results from surface-water and sediment sampling are presented in Tables 4-2-5 and 4-2-6. Concentrations of vinyl chloride, cis-1,2-DCE, and 1,1-DCA were detected at concentrations slightly above detection limits in surface water at Site 2B. Concentrations ranged from 1.1 to 2.4 ppb in 2B-SW2 and 2B-SW4, but VOCs were absent in 2B-SW1 and 2B-SW3. No polynuclear aromatic compounds were detected in any of the surface water samples. Chlorinated volatile organic compounds were not detected in any sediment samples, but 15 PAH compounds were detected in 2B-SD2 and 2B-SD4. Concentrations were higher in the upstream sample 2B-SD2 than in the downstream sample 2B-SD4.

Health and Environmental Assessment

Site 2B contaminants that exceeded federal standards are presented in Table 4-2-7. The contaminants of concern include vinyl chloride, cis-1,2-DCE, TCE and 1,2-DCA. Vinyl chloride concentrations exceed the established MCL of 2 ppb in 2B-MW6 (3.8 ppb), 2B-MW7 (8.3 ppb), 2B-MW14 (3.2 ppb), 2B-MW15 (21 ppb) and 2B-MW16 (6.4 ppb); that is, only in the western plume. TCE concentrations in three monitoring wells (2B-MW1, 2B-MW3, and 2B-MW7) were considerably above the MCL of 5 ppb. TCE concentrations in these wells were 250 ppb, 240 ppb, and 12 ppb, respectively. Cis-1,2-DCE concentrations exceeded the MCL (70 ppb) in 2B-MW1 (320 ppb) and in 2B-MW3 (180 ppb). The only other contaminant to exceed an MCL was 1,2-DCA, which was present at 25 ppb in 2B-MW14 versus an MCL of 5.

Seven PAHs were present in the ditch sediments at concentrations that exceeded NOAA ER-M guideline concentrations (1991). This guideline is explained in Appendix A. Benzo(a)anthracene was 6,000 ppb in 2B-SD2 versus a guideline of 1,600 ppb. Benzo(a)pyrene was 6,400 ppb in 2B-SD2 versus the NOAA guidelines of 2,500 ppb. NOAA guidelines also were exceeded for fluoranthene (2,300 to 13,000 versus 3,600 ppb), phenanthrene (2,100 to 7,400 versus 1,380 ppb), anthracene (350 to 2,200 versus 960 ppb), chrysene (1,000 to 7,900 versus 2,800 ppb), and pyrene (1,900 to 11,000 versus 2,200 ppb). No organics were detected in 2B-SD1. The presence of high levels in 2B-SD2 near the ditch effluent pipe may indicate an upstream source for these PAHs. Benzo(a)anthracene and benzo(a)pyrene concentrations in 2B-SD2 also exceed NOAA sediment guidelines of 1,600 and 2,500 ppb, respectively.

Two of the seven PAHs, fluoranthene and phenanthrene, detected in the sediment at Site 2B also may exceed sediment criteria proposed by the EPA (1991). However, these criteria are based on the percentage of organic carbon in the sediment. An assumed percentage of organic carbon in the sample of 1 percent was used for this comparison. Because total organic carbon was not analyzed, it cannot be determined definitely whether these proposed criteria were exceeded. Nonetheless, these criteria are listed in Table 4-2-7. See Appendix A for additional details on sediment standards.

Table 4-2-5
ORGANIC COMPOUNDS IN SURFACE WATER AT SITE 2B
RESULTS OF RFI AND PREVIOUS INVESTIGATIONS
(All data in $\mu g/L$)

Analyte	Detection Limit	2B-SW1			2B-SW2		2B-SW3	2B-SW4
		Aug. 90	Jan. 93		Aug. 90	Jan. 93	Jan. 93	Jan. 93
			Initial	Duplicate				
EDB	0.02	*	NA	NA	*	NA	NA	NA
TPH	60	1,700	NA	NA	2,610	NA	NA	NA
Volatile Organic Compounds								
Acetone	10	19[b]	NA	NA	12[b]	NA	NA	NA
2-Hexanone	10	1[j]	NA	NA	*	NA	NA	NA
Methylene Chloride	5	4[b,j]	*	*	4[bj]	*	*	*
Xylenes (Total)	5	2[bj]	NA	NA	*	NA	NA	NA
Cis-1,2-dichloroethylene	1			*		1.1		*
Vinyl chloride	1			*		2.0		*
1,1-Dichloroethane	1, 5	*	*	*	*	2.4	*	1.5
Polynuclear Aromatics (PAHs)	2	NA	*	NA	NA	*	*	*

Notes:

EDB - Ethylene Dibromide
TPH - Total Petroleum Hydrocarbons
* - Concentration below detection limit

[b]Compound found in laboratory blank as well as sample; concentration is less than 10 times blank concentration.
[j]Estimated value; measured value is less than the accurate quantitative detection limit.

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Table 4-2-6
ORGANIC COMPOUNDS IN SEDIMENT AT SITE 2B
January 1993
(All data in μg/kg)

Analyte	2B-SD1		2B-SD2	2B-SD4
	Initial	Duplicate		
Chlorinated Volatile Organic Compounds	*	*	*	*
Polynuclear Aromatics (PAHs)				
2-Methylnaphthalene	*	*	*	420
1-Methylnaphthalene	*	*	*	430
Acenaphthene	*	*	*	350
Fluorene	*	*	*	320
Phenanthrene	*	*	7,400	2,100
Anthracene	*	*	2,200	350
Fluoranthene	*	*	13,000	2,300
Pyrene	*	*	11,000	1,900
Benzo (a) anthracene	*	*	6,000	930
Chrysene	*	*	7,900	1,000
Benzo (b) fluoranthene	*	*	7,700	730
Benzo (k) fluoranthene	*	*	6,500	510
Benzo (a) pyrene	*	*	6,400	880
Indeno (1,2,3-cd) pyrene	*	*	5,100	500
Benzo (g,h,i) perylene	*	*	3,200	410

Notes:

All chlorinated volatile organic and polynuclear aromatic compounds not listed in the table above were analyzed for, but were below the detection limit in all samples.
QC Sampling: 2B-SD30 is a duplicate of 2B-SD1.
* Concentration below detection limit.
The proposed sample 2B-SD3 could not be collected.

Table 4-2-7
CONSTITUENTS DETECTED AT SITE 2B THAT EXCEEDED POTENTIALLY APPLICABLE FEDERAL STANDARDS AND GUIDELINES
January 1993
(All data in ppb)

Human Health Assessment

Compound	Location	Concentration (ppb)	Health Based Criteria for Carcinogens	Health Based Criteria for Systemic Toxicants	MCL	MCLG	Proposed RCRA Action Level
cis-1,2-DCE	2B-MW1 2B-MW3	320 180	NS	NS	70	70	--
TCE	2B-MW1 2B-MW3 2B-MW7	250 240 12	5	NS	5	0	5
Vinyl Chloride	2B-MW6 2B-MW7 2B-MW14 2B-MW15 2B-MW16	3.8 8.3 3.2 21 6.4	NS	NS	2	0	2
1,2-DCA	2B-MW14	25	5	NS	5	0	5

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Table 4-2-7
CONSTITUENTS DETECTED AT SITE 2B THAT EXCEEDED POTENTIALLY APPLICABLE FEDERAL STANDARDS AND GUIDELINES
January 1993
(All data in ppb)

Ecological Assessment[a]

Compound	Location Detected	Concentration (ppb)	NOAA ER-M Sediment Guideline	EPA Proposed Sediment Criteria
Benzo(a)anthracene	2B-SD2 2B-SD4	6,000 930	1,600	NS
Benzo(a)pyrene	2B-SD2 2B-SD4	6,400 880	2,500	NS
Fluoranthene	2B-SD2	13,000	3,600	11,020
Phenanthrene	2B-SD2 2B-SD4	7,400 2,100	1,380	1,200
Anthracene	2B-SD2	2,200	960	NS
Chrysene	2B-SD2	7,900	2,800	NS
Pyrene	2B-SD2 2B-SD4	11,000 1,900	1,200	NS

Notes: Health-based criterion were extracted from the RFI Guidance Document EPA 530/SW-89-031. The proposed RCRA action levels were printed in the Federal Register dated 27 July 1990. MCL and MCLG standards are printed from the drinking water regulations and health advisories, December 1992.
[a]See Appendix A for explanation of ecological criteria and guidelines.
NS = No standard.

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Fate and Transport

In situ conductivity tests conducted during the interim RFI indicated that the hydraulic conductivity of the sands and silty sands through which the shallow wells are screened averaged 3.0×10^{-3} cm/sec. The rate of groundwater flow can be estimated by Darcy's Law by using a range of hydraulic gradients from the February 1993 data and an assumed porosity of 20 percent. This analysis indicates that the average linear velocity of groundwater in the Columbia aquifer is approximately 10 feet per year from 2B-MW3 to 2B-MW8 and 20 ft/year from 2B-MW1 to 2B-MW2 in the eastern source area near Line Shack 131 and 50 feet per year in the western source area near Line Shack 134. No *in situ* conductivity tests of the deep zones have been conducted to date. Because there are only two wells at Site 2B, the horizontal hydraulic gradient over the deep interval cannot be determined.

The main transport mechanisms at Site 2B are groundwater and surface-water. Contaminated groundwater from the western source area appears to be discharging to the ditch near well 2B-MW7. The plume in the eastern source area does not appear to extend to the ditch. Chlorinated volatiles in surface water are likely to be transported to the southeast in the drainage ditch. This ditch ultimately flows off the station to the south as shown in the drainage map in Chapter 2 (Figure 2-3). VOC concentrations adjacent to Site 2B are quite low. They are likely to be diluted downstream of Site 2B by other waters draining to the ditch along its course. The PAHs in sediments, which probably originate upstream, are likely to be transported downstream to some degree during storm events.

Recommendations

Groundwater contamination at Site 2B has been characterized extensively and its extent is generally well known. The initiation of a CMS of remediation options for soil, sediments, and groundwater is recommended. A more complete analysis of risk will be part of the CMS activities; however, current data already support initiating a CMS in the absence of detailed risk analysis.

Site 2C—Line Shack 400 Disposal Area

Site Location and History

Site 2C is encompassed by Line Shack 400 and Buildings 301, 401, and 404. This general area, which is part of FITWING, has been and continues to be used for aircraft maintenance and cleaning. In earlier years, Navy personnel disposed of various maintenance and cleaning chemicals similar to those discharged at Site 2B. These chemicals potentially include waste oil, hydraulic fluid, PD680, paint stripper, thinner, Turco, naphtha, and B&D 3400 Engine Cleaner (RGH, 1984). Waste disposal occurred near Line Shack 400 starting in 1963, the year the line shack was constructed, until the early 1980s, when a hazardous waste recovery program was instituted (RGH, 1984). The area around the line shack originally had an earthen surface but it was capped with 15 inches of concrete in the early 1980s (RGH, 1984). A disposal area southwest of Building 400 was reported to be visible in 1971 air photographs reviewed during the IAS (RGH, 1984). It is not known if the soil was removed and if so, where it was taken for disposal (RGH, 1984).

Past Investigations and RFI Site Activities

Environmental investigations at Site 2C have occurred on two previous occasions: the Line Shack Inspection Study in 1988 (CH2M HILL, 1989) and the Interim RFI in 1990 (CH2M HILL, 1991). These previous studies showed that groundwater is contaminated with several volatile organic compounds.

The purpose of the RFI activities at Site 2C were to determine as accurately as possible the sources and routes of contamination. The RFI was designed to determine the vertical extent of groundwater contamination, to define the nature and extent of soil contamination in the suspected source area adjacent to Building 400, and to identify any other source areas. The RFI also was designed to characterize the nature of the soil contamination in the ditch in the lawn northwest of B Avenue and to determine the lateral extent of contaminant migration in the groundwater southeast of B Avenue.

The Site 2C field investigation consisted of:

- The collection of 13 in-situ groundwater samples in an interactive program of hydraulic probe sampling (2C-GP1 through 2C-GP13)
- The collection of 3 soil samples (2C-SB1 through 2C-SB3) in the probable source area near Line Shack 400
- The collection of 2 soil samples (2C-SS1 and 2C-SS2) from the drainage ditch that flows through the central portion of Site 2C

- The installation of two deep monitoring wells (2C-MW9D and 2C-MW1D) and four shallow monitoring wells (2C-MW10, -MW11, -MW12, -MW13)

- The sampling of groundwater at all new and existing wells

All RFI sampling locations are shown in Figure 4-3-1. Sampling depths were 9 to 12 feet for *in situ* groundwater, 1 to 1.5 feet for soils in the ditch, and 1 to 3, 3 to 5, or 5 to 7 feet for the soil borings. The screened intervals of the monitoring well are shown in Table 4-3-1.

Environmental Setting

Site 2C is a large area consisting of both developed and undeveloped areas. Most of the developed portion of the site is within the flightline. This portion of the site is flat and covered in asphalt or concrete for use as parking lots for aircraft maintenance and cleaning. The area outside the flightline includes an area of lawn northwest of B Avenue and a large forested area southeast of B Avenue. The lawn area is relatively flat except for a small ditch. The forest floor generally slopes to the southwest. The soils in the undeveloped part of the site are classified as Acredale-Urban. This series generally consists of upland soils and soils that have been previously disturbed by development activities. Figure 4-2-2 is an ecological map that includes Site 2C.

Ecology

Surface Water Resources. Surface water flows from the paved portion of the site into flush-mounted drains that direct flow to an oil-water separator and then to the sanitary sewer. The grassy area drains into a small ditch that cuts across the lawn, toward a culvert at B Avenue. This ditch receives runoff from Buildings 404 and 400 during storm events but is normally dry. The ditch may be contaminated, based on the presence of a black material that covers most of the bottom of the ditch.

The small ditch flows from the culvert at B Avenue where it connects with a larger ditch. The larger ditch runs southwest along B Avenue and connects with another ditch at 4th Street. At the time of the survey, ponded water was present in the portion of the ditch nearest the culvert. The rest of the B Avenue ditch appears to receive flow intermittently. The ditch at 4th Street flows under B Avenue and through a culvert. This segment of the ditch may flow more continuously because it receives additional flow from the area near Buildings 500 and 402.

Wetlands. Wetlands are limited to ditch bottoms where water accumulates for long periods. These small emergent wetlands are usually mowed, and may not provide valuable habitat. The forested area, a large rectangular area, encompassing approximately 4.5 acres, may provide valuable habitat in an area that is otherwise entirely developed. The forested area appears to be mostly upland on the basis of the vegetation present. Soils in

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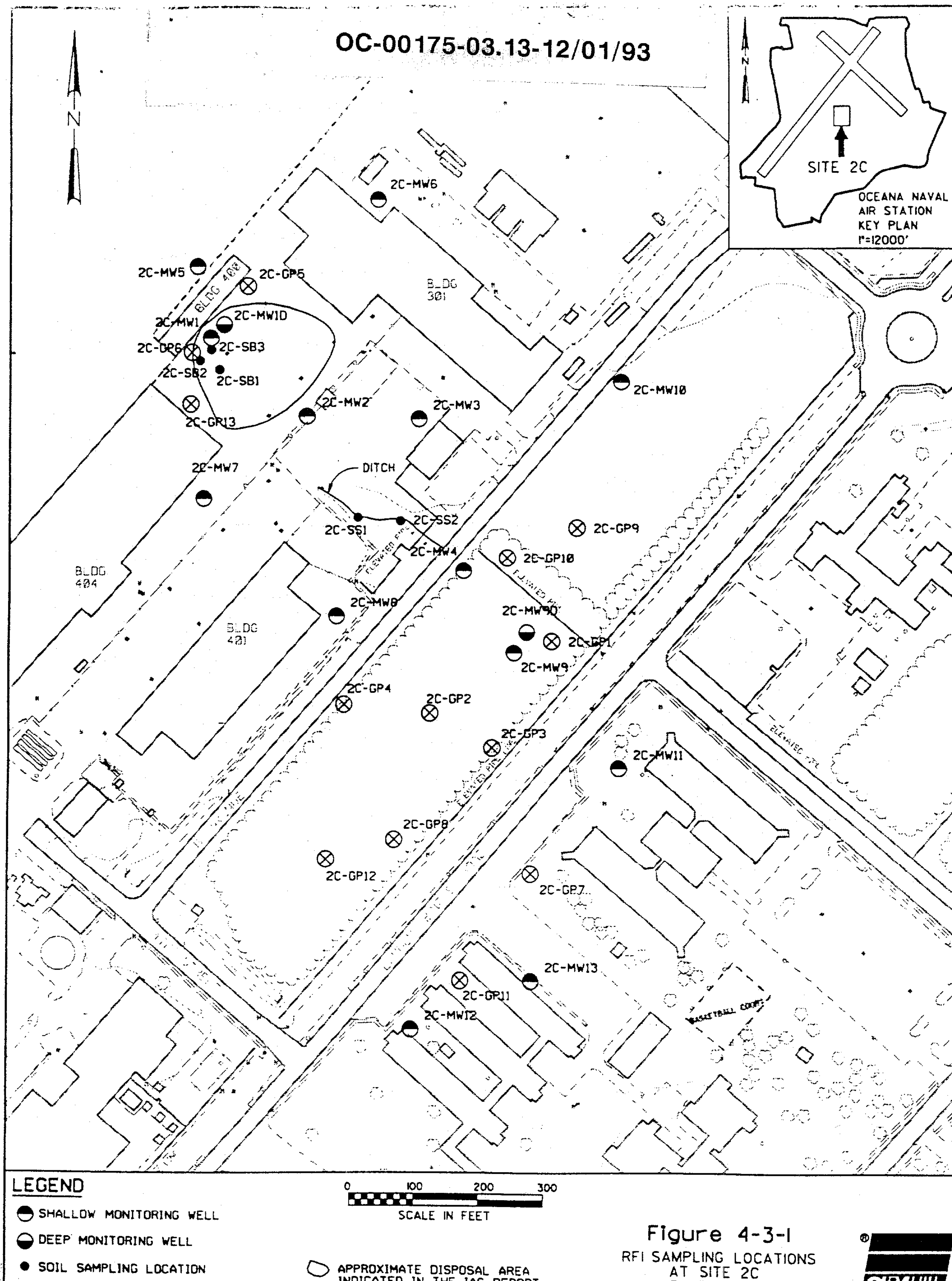

Figure 4-3-1
RFI SAMPLING LOCATIONS
AT SITE 2C
JANUARY-FEBRUARY 1993

CH2MHILL

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12-Oct-1993

Table 4-3-1
SITE 2C MONITORING WELL SUMMARY

Well Number	Date Installed	Ground Elevation (feet above MSL)	Total Depth (feet)	Screened Interval (feet below ground surface)
2C-MW1	09/13/88	20.5	20	10-20
2C-MW1D	12/17/92	20.43	62	45-55
2C-MW2	09/09/88	20.8	20	10-20
2C-MW3	09/09/88	20.0	18	8-18
2C-MW4	09/14/88	17.0	18	8-18
2C-MW5	07/12/90	20.4	16	6-16
2C-MW6	06/29/90	20.7	21	11-21
2C-MW7	07/05/90	20.8	19	9-19
2C-MW8	07/03/90	19.0	17	7-17
2C-MW9	07/03/90	17.0	17.5	7.5-17.5
2C-MW9D	12/15/92	17.1	57	42-52
2C-MW10	12/10/92	18.24	20	10-20
2C-MW11	12/09/92	18.47	23	13-23
2C-MW12	12/09/92	17.84	23	13-23
2C-MW13	12/11/92	18.49	21	11-21

this area consist of sandy silts underlain by sand. Small pockets of depressional wetlands may occur, especially in the northeastern portion of the forest. The site becomes more obviously upland toward the southwest.

Vegetation. The canopy cover in the forested area is dominated by sweetgum, maple, various oak species, beech, and tulip poplar. The understory was dominated by giant cane in the northeastern portion, and greenbriar in the southwestern portion of the forest. Other forest species observed include Japanese honeysuckle, paw paw, eastern hop hornbeam, loblolly pine, black cherry, ironwood, and eastern red cedar.

Except for a few cleared paths, no signs of stress were observed in the forested area. However, the small ditch in the grassy area showed signs of vegetative stress. Most of the ditch slopes are regularly mowed lawn. However, a few sedges and rushes were growing in the ditch bottom. Virtually all of these plants had turned black or dark, and were dying. No other vegetation was observed in this portion of the ditch. The B Avenue ditch had little or no vegetation in it, perhaps because of the shading and leaf litter caused by the overstory.

Wildlife. Neither birds nor mammals, nor any of their signs were observed near the developed portion of Site 2C. However, numerous birds were observed in the forested area. Some of these were feeding song sparrows, black capped chickadees, and tufted titmouse. Signs indicating the presence of squirrels, raccoons, and woodpeckers also were observed in the area.

Geologic and Hydrogeologic Characteristics

On the basis of the boreholes drilled during the RFI and previous investigations, the shallow geology is composed of a fine-grained silt and clay soil zone in the top 1 to 3 feet underlain by silts and sands to depths of 10 feet. This silt and sand layer is underlain by clean to silty sands to a depth of at least 60 feet. Sediments to a depth of approximately 24 feet are the Columbia Group sediments described in Chapter 2. These sediments are underlain by the Yorktown Formation. Two deep wells (2C-MW1D and 2C-MW9D) installed during the RFI penetrated the Yorktown Formation. On the basis of the first appearance of shells or shell fragments, the top of the Yorktown is at approximately 24 feet at Site 2C. The shallow wells are installed within the clean to silty sands of the Columbia Group. The deep wells are installed within silty sands of the Yorktown Formation. The arithmetic mean hydraulic conductivity of the Columbia Group sands measured in 1990 was 5×10^{-3} cm/sec.

The water-level measurements collected at Site 2C on February 23, 1993, are listed in Table 4-3-2. Figure 4-3-2 shows the equipotential contour lines in the shallow Columbia Group aquifer. The deep well water elevations are shown; however, they are not contoured because data is insufficient. The data show that groundwater flows to the south.

Table 4-3-2
SITE 2C WATER-LEVEL DATA
FEBRUARY 23, 1993

Well	Depth to Water (Feet below Survey Datum)	Water-Level Elevation (Feet Above Mean Sea Level)
2C-MW1	6.52	13.62
2C-MW1D	6.89	13.54
2C-MW2	6.76	13.47
2C-MW3	7.75	13.54
2C-MW4	6.34	13.22
2C-MW5	6.63	13.79
2C-MW6	9.26	13.92
2C-MW7	7.41	13.40
2C-MW8	5.91	13.14
2C-MW9	6.34	12.99
2C-MW9D	6.56	12.89
2C-MW10	4.65	13.59
2C-MW11	5.94	12.53
2C-MW12	6.12	11.72
2C-MW13	6.73	11.76

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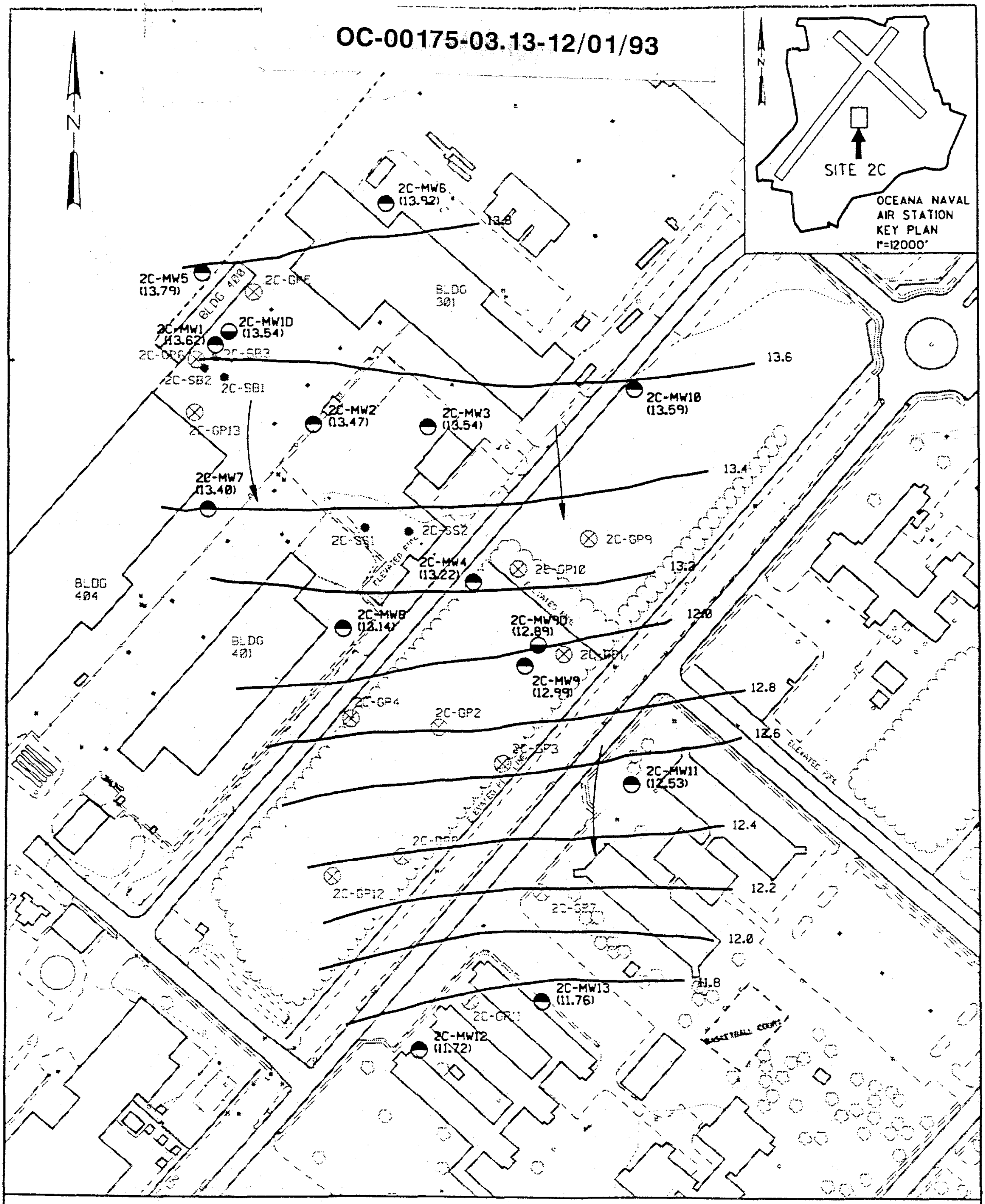

0 100 200 300
SCALE IN FEET

LEGEND

- SHALLOW MONITORING WELL
- DEEP MONITORING WELL
- ( ) WATER LEVEL ELEVATIONS
- SOIL SAMPLING LOCATION
- HYDRAULIC PROBE SAMPLING LOCATION
- DIRECTION OF SHALLOW GROUNDWATER FLOW

Figure 4-3-2
WATER LEVEL ELEVATIONS WITH EQUIPOTENTIAL CONTOURS FOR THE SHALLOW AQUIFER AT SITE 2C
FEBRUARY 23, 1993

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The horizontal gradient is approximately 0.002 ft/ft from 2C-MW3 to 2C-MW12. Horizontal gradients appear to be relatively uniform across Site 2C, so this value is generally representative of the site.

Water levels at the two shallow/deep wells pairs both suggest downward flow from the Columbia into Yorktown at Site 2C. The downward vertical gradient between these wells on February 23 was approximately 0.003 ft/ft at 2C-MW9/9D and 0.002 ft/ft at 2C-MW1/1D, calculated from the center of the screens in each well.

Contamination and Extent

In Situ Groundwater Sampling

In situ groundwater samples were collected with the hydraulic probe from 9 to 12 feet below ground surface in two areas: (1) near Line Shack 400, and (2) southeast of B Avenue. The results of this sampling are presented in Table 4-3-3 and depicted in Figure 4-3-3. Groundwater at Site 2C is contaminated in two adjoining areas, one near Line Shack 400 and a second in the woods directly southeast of Line Shack 400. The area adjacent to Line Shack 400 had been identified previously as a probable source area for the chlorinated volatiles detected in groundwater. *In situ* groundwater samples collected from this area (2C-GP5, 2C-GP6, 2C-GP13) contained 1,1-dichloroethylene (1,1-DCE), vinyl chloride and cis-1,2-dichloroethylene (cis-1,2-DCE).

The second major source area for chlorinated volatiles is in the woods near 2C-MW9. Sampling in the area southeast of B Avenue indicated that contamination extends through the wooded area and across London Bridge Road to Buildings 419 and 420. The principal constituents detected in *in situ* samples from this area were TCE, vinyl chloride and trans- and cis-1,2-DCE. Vinyl chloride was detected in trace amounts in 2C-GP9 and was present at 15 ppb in 2C-GP7, adjacent to barracks 419. TCE was detected at sampling locations 2C-GP10, 2C-GP1, 2C-GP3, and 2C-GP7; therefore, both TCE and vinyl chloride contamination extend southeast across London Bridge Road and into the barracks area. Some contamination by trans- and cis-1,2-DCE was detected in 2C-GP2, 2C-GP8, 2C-GP12, 2C-GP10 and 2C-GP3, but was absent in 2C-GP4 and 2C-GP11. No 1,2-DCE isomers were detected in *in situ* groundwater samples southeast of London Bridge Road.

Monitoring Wells

The analytical laboratory results for groundwater sampling from monitoring wells during the RFI and previous studies are listed in Table 4-3-4. The monitoring well samples were analyzed for chlorinated VOCs. Well 2C-MW1 also was analyzed for VOCs. The monitoring well data confirm that a variety of chlorinated VOCs are in the groundwater at this site. 1,1-DCA, cis-1,2-DCE, TCE, and vinyl chloride all were detected in monitoring wells. Chloroethane, 1,2-dichlorobenzene, and trichlorofluoromethane also were detected; however, they are limited to well 2C-MW4.

Table 4-3-3
ORGANIC COMPOUNDS IN IN-SITU GROUNDWATER SAMPLES AT SITE 2C
November 1992
(All data in ppb)

Analyte	2C-GP1	2C-GP2	2C-GP3	2C-GP4	2C-GP5	2C-GP6	2C-GP7	2C-GP8	2C-GP9	2C-GP10	2C-GP11		2C-GP12	2C-GP13	
											Field GC	Standard Laboratory GC[a]		Field GC	
Volatile Organic Compounds															
Vinyl Chloride	*	*	*	*	4.3	7.0	15	*	*	*	*	*	*	130	
1,1-Dichloroethylene	*	*	*	*	4.5	8.0	*	*	*	*	*	*	*	2,600	
trans-1,2-Dichloroethylene	10	9.7	*	*	*	*	*	*	*	8.1	*	*	*	*	
cis-1,2-Dichloroethylene	*	*	21	*	*	15	*	17	*	110	*	*	28	16	
1,1-Dichloroethane	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
1,1,1,-Trichloroethane	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
Trichloroethylene	3.3	*	3.0	*	*	*	4.7	*	*	10	*	*	*	*	
Benzene	*	*	*	*	*	*	*	*	*	*	*	NA	*	*	
Toluene	*	*	*	*	*	*	*	*	*	*	*	NA	*	*	
Ethylbenzene	*	*	*	*	*	*	*	*	*	*	*	NA	*	*	
Total Xylenes	*	*	*	*	*	*	*	*	*	*	*	NA	*	*	
Methylene Chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.2	NA	NA	
Dichlorodifluoromethane	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	*	NA	NA	21
Total Petroleum Volatiles	*	*	*	*	*	*	*	*	*	*	*	NA	*	*	NA

Notes:
[a]The data validation process qualified VOC detects as estimated and rejected nondetect results because the sample containers had headspace.
[b]During the data validation process, positive VOC results were qualified as estimated and nondetects were rejected as unusable because the volatile vials contained headspace. 1,1-DCE and dichlorodifluoromethane were not confirmed on the second column analyses.
All volatile organic compounds not reported were below detection limits in all samples. Methylene chloride and dichlorodifluoromethane were not analyzed by the mobile lab, but were analyzed by the standard laboratory.
NA - Not analyzed.
*The value was less than the IDL or was not detected.
QC Sampling - The duplicates for 2C-GP11 and 2C-GP13 were submitted for analysis at the CH2M HILL Analytical Laboratory in Montgomery, Alabama.

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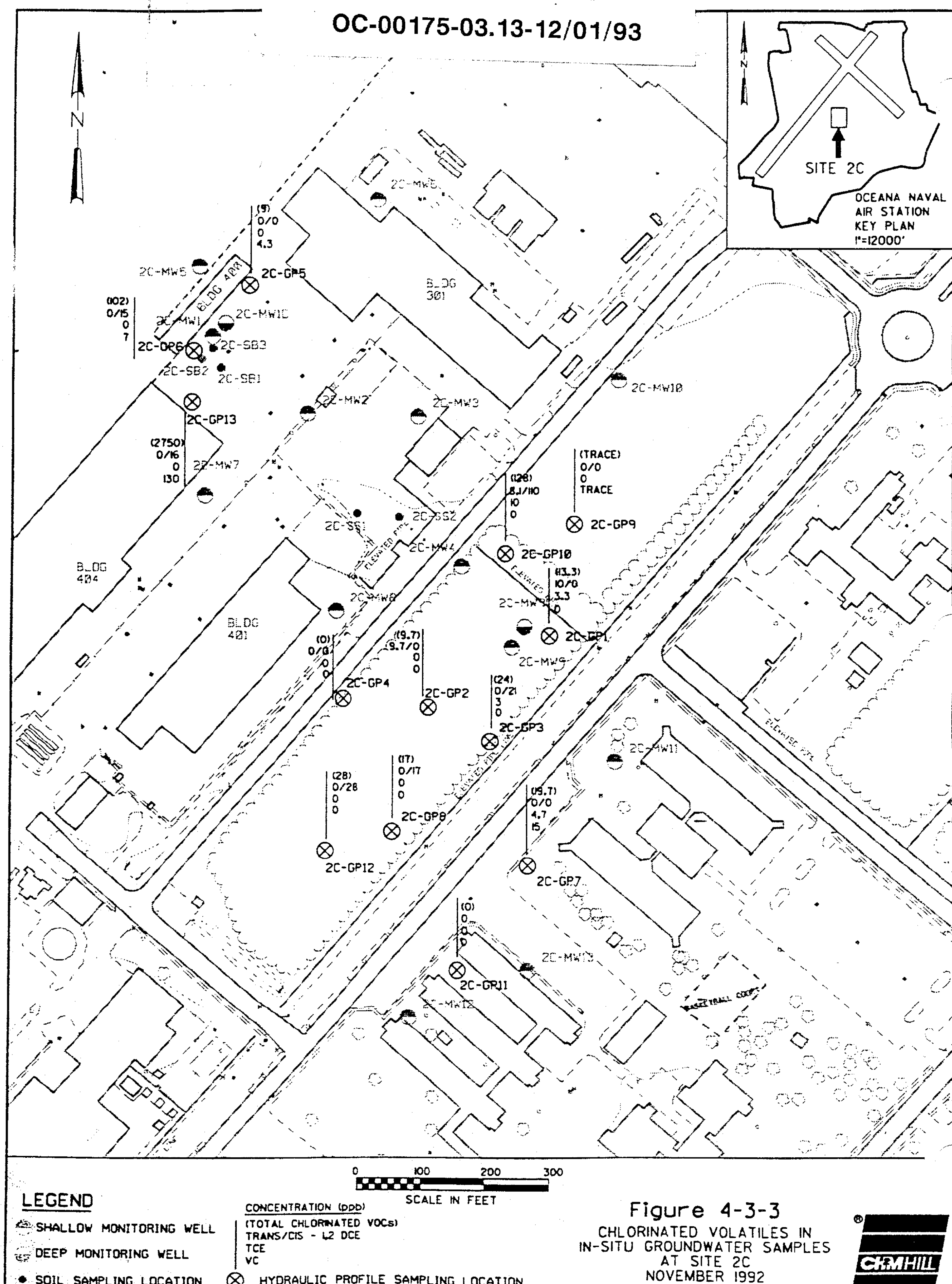

Figure 4-3-3
CHLORINATED VOLATILES IN IN-SITU GROUNDWATER SAMPLES AT SITE 2C
NOVEMBER 1992

Table 4-3-4
ORGANIC COMPOUNDS IN GROUNDWATER AT SITE 2C
RESULTS OF RFI AND PREVIOUS INVESTIGATIONS
(All data in $\mu g/l$)

Analyte	Detection Limit	2C-MW1				2C-MW1D	2C-MW2			2C-MW3		
		Sept. 88	Aug. 90		Jan. 93	Jan. 93	Sept. 88	Aug. 90	Jan. 93	Sept. 88	Aug. 90	Jan. 93
			Initial	Duplicate								
EDB	0.02	NA	•	•	NA	NA	NA	•	NA	NA	•	NA
TPH	60	NA	260	360	NA	NA	NA	280	NA	NA	290	NA
Semivolatile Compounds	10, 50	NA	NA	NA	•	NA	NA	NA	NA	NA	NA	NA
Volatile Organic Compounds												
Acetone	10	13	7 bj	210 b	NA	NA	30	22 b	NA	•	9 bj	NA
Benzene	5	7	2 j	•	NA	NA	•	2 j	NA	5	4 j	NA
2-Butanone (MEK)	10	•	•	•	NA	NA	•	13	NA	•	•	NA
Chlorobenzene	1, 5	•	1 j	•	•	•	•	•	•	•	•	•
Chloroethane	1, 10	•	•	•	•	•	•	•	•	•	•	•
1,1-Dichloroethane	1, 5	•	•	•	•	•	•	•	•	•	3 j	2.2
1,2-Dichloroethane	1, 5	•	•	•	•	•	•	•	•	•	•	•
1,1-Dichloroethylene	1, 5	•	•	•	•	•	•	•	•	•	•	•
cis-1,2-Dichloroethylene	1.0	NA	NA	NA	•	•	NA	NA	•	NA	NA	•
1,2-Dichloroethylene (Total)	5	2,400	140	130	NA	NA	•	3 j	NA	•	•	NA
Ethylbenzene	5	15	1 j	•	NA	NA	•	•	NA	•	1 j	NA
Methylene chloride	1, 5	•	4 bj	170 b	•	•	•	5 b	•	•	4 bj	•
Toluene	5	34	14	20 j	NA	NA	•	•	NA	•	•	NA
Trichloroethylene	1, 5	•	•	•	•	•	•	•	•	•	•	•
Vinyl chloride	1, 10	2,500	2,000	1,900	210	•	37	22	25	•	11	6.0
Xylenes (total)	5	•	15	47 bj	NA	NA	•	2 bj	NA	5	3 bj	NA
1,2-Dichlorobenzene	1.0	NA	NA	NA	•	•	NA	NA	•	NA	NA	•
Trichlorofluoromethane	1.0	NA	NA	NA	•	•	NA	NA	•	NA	NA	•

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Table 4-3-4
ORGANIC COMPOUNDS IN GROUNDWATER AT SITE 2C
RESULTS OF RFI AND PREVIOUS INVESTIGATIONS
(All data in $\mu g/l$)

Analyte	Detection Limit	2C-MW4			Production Well	2C-MW5		2C-MW6		2C-MW7	
		Sept. 88	Aug. 90	Jan. 93	Sept. 88	Aug. 90	Jan. 93	Aug. 90	Jan. 93	Aug 90	Jan. 93
EDB	0.02	NA	•	NA	NA	NA	NA	•	NA	•	NA
TPH	60	NA	380	NA	NA	160	NA	•	NA	140	NA
Semivolatile Compounds	10, 50	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Volatile Organic Compounds											
Acetone	10	•	5 bj	NA	18	10 b	NA	9 bj	NA	10 b	NA
Benzene	5	•	1 j	NA	•	•	NA	2 j	NA	•	NA
2-Butanone (MEK)	10	•	•	NA	•	•	NA	•	NA	•	NA
Chlorobenzene	1, 5	•	•	•	•	•	•	•	•	•	•
Chloroethane	1, 10	78	31	4.2	•	•	•	•	•	•	•
1,1-Dichloroethane	1, 5	25	11	19	•	•	6	•	•	4 j	•
1,2-Dichloroethane	1, 5	•	2 j	•	•	•	•	•	•	•	•
1,1-Dichloroethylene	1, 5	•	•	•	•	•	•	•	•	•	•
cis-1,2-Dichloroethylene	1.0	NA	NA	30	NA	NA	12	NA	•	NA	47
1,2-Dichloroethylene (total)	5	12	11	NA	•	9	NA	•	NA	34	NA
Ethylbenzene	5	•	•	NA	•	•	NA	2 j	NA	•	NA
Methylene chloride	1, 5	•	6 b	•	•	5 j	•	8 b	•	5 b	•
Toluene	5	•	1 j	NA	•	•	NA	•	NA	•	NA
Trichloroethylene	1, 5	•	2 j	1.7	•	•	•	•	•	•	•
Vinyl chloride	1, 10	210	81	83	•	•	11	•	•	13	•
Xylenes (total)	5	•	2 j	NA	•	2 bj	NA	5 b	NA	2 bj	NA
1,2-Dichlorobenzene	1.0	NA	NA	2	NA	NA	•	NA	•	NA	•
Trichlorofluoromethane	1.0	NA	NA	3.8	NA	NA	•	NA	•	NA	•

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Table 4-3-4
ORGANIC COMPOUNDS IN GROUNDWATER AT SITE 2C
RESULTS OF RFI AND PREVIOUS INVESTIGATIONS
(All data in $\mu g/l$)

Analyte	Detection Limit	2C-MW8			2C-MW9			2C-MW9D	2C-MW10	2C-MW11	2C-MW12	2C-MW13
		Aug. 90	Jan. 93		Aug. 90	Jan. 93		Jan 93	Jan. 93	Jan. 93	Jan. 93	Jan. 93
			Initial	Duplicate		Initial	Duplicate					
EDB	0.02	•	NA	NA	•	NA	NA	NA	NA	NA	NA	NA
TPH	60	150	NA	NA	170	NA	NA	NA	NA	NA	NA	NA
Semivolatile Compounds	10, 50	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Volatile Organic Compounds												
Acetone	10	8 bj	NA	NA	86 bj	NA	NA	NA	NA	NA	NA	NA
Benzene	5	3 j	NA	NA	•	NA	NA	NA	NA	NA	NA	NA
2-Butanone (MEK)	10	•	NA	NA	•	NA	NA	NA	NA	NA	NA	NA
Chlorobenzene	1, 5	•	•	•	•	•	•	•	•	•	•	•
Chloroethane	1, 10	•	•	•	•	•	•	•	•	•	•	•
1,1-Dichloroethane	1, 5	78	5.6	5.9	•	•	•	•	4.4	4.3	•	•
1,2-Dichloroethane	1, 5	•	•	•	•	•	•	•	•	•	•	•
1,1-Dichloroethylene	1, 5	3 j	•	•	•	•	•	•	•	•	•	•
cis-1,2-Dichloroethylene	1.0	NA	1.4	1.4	NA	1,500	1,600	1.7	2.3	1.2	12	110
1,2-Dichloroethylene (total)	5	66	NA	NA	1,300	NA	NA	NA	NA	NA	NA	NA
Ethylbenzene	5	•	NA	NA	•	NA	NA	NA	NA	NA	NA	NA
Methylene chloride	1, 5	5 b	•	•	21 bj	•	•	•	•	•	•	•
Toluene	5	•	NA	NA	•	NA	NA	NA	NA	NA	NA	NA
Trichloroethylene	1, 5	12	•	•	63	29	36	•	•	•	8.8	17
Vinyl chloride	1, 10	320	11	11	380	280	340	•	1.1	1.4	1.7	70
Xylenes (total)	5	2 bj	NA	NA	•	NA	NA	NA	NA	NA	NA	NA
1,2-Dichlorobenzene	1.0	NA	•	•	NA	•	•	•	•	•	•	•
Trichlorofluoromethane	1.0	NA	•	•	NA	•	•	•	•	•	•	•

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Table 4-3-4
ORGANIC COMPOUNDS IN GROUNDWATER AT SITE 2C
RESULTS OF RFI AND PREVIOUS INVESTIGATIONS
(All data in µg/l)

Notes:

- The detection limits for the volatile organic compounds analyzed in 1/93 were 1.0 µg/l. This limit is presented along with the previous detection limits.
- The detection limits for the semivolatile compounds analyzed at 2C-MW1 are either 10.0 or 50.0 µg/l. No semivolatile compounds were detected.
- All volatile and semivolatile organic compounds not listed above were not detected in any samples at any time. Trans-1,2-DCE was not detected.

EDB = Ethylene Dibromide
TPH = Total Petroleum Hydrocarbons
NA = Not analyzed
b Compound found in laboratory blank as well as sample; sample concentrations is less than 10 times blank concentration.
j Estimated value; measured value is less than the accurately quantitative detection limit.
*Concentration below detection limit.
QC Sampling: 2C-MW33 is a duplicate of 2C-MW9 and 2C-MW32 is a duplicate of 2C-MW8.
2C-MW1 was sampled in January 1993 for the Semivolatile Compound List Method 8270.

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Figure 4-3-4 illustrates the concentrations of total chlorinated VOCs and the specific constituents cis-1,2-DCE, TCE, and vinyl chloride in the Site 2C monitoring wells in January 1993. This figure shows that groundwater at Site 2C is contaminated with chlorinated VOCs in a broad area extending from 2C-MW5 on the north to 2C-MW12 on the south. The VOC contamination is present across this entire area but is concentrated in one area adjacent to Line Shack 400 and another in the woods near 2C-MW9. Concentrations in wells 2C-MW2 and 2C-MW3 between these two areas are considerably lower, as shown in the figure; therefore, the contamination can be viewed as two adjoining plumes of VOCs. The two plumes consist of several VOCs, each with a somewhat different distribution; however, VOC contamination will be discussed as a whole.

VOC contamination extends from Line Shack 400 to the barracks southeast of London Bridge Road. VOCs were detected in all shallow monitoring wells except 2C-MW6, which is hydraulically upgradient of the source area. VOC concentrations are particularly high in 2C-MW9 (1,976 ppb), 2C-MW1 (210 ppb), and 2C-MW13 (197 ppb). Vinyl chloride and cis-1,2-DCE are the primary constituents of the VOC contamination. The full extent of VOC contamination has not been determined by the sampling to date. VOCs are present on the northern limit of the monitoring network in 2C-MW5, along the eastern limit in 2C-MW10 and 2C-MW11, on the western limit in 2C-MW7 and 2C-MW8, and at the downgradient limit in 2C-MW13 and 2C-MW12. However, VOCs are present at 8.2 ppb or less in wells 2C-MW3, 2C-MW10, and 2C-MW11 on the east, suggesting that contamination does not extend much farther to the east.

Some important changes in VOC concentrations since 1988 are notable. In 2C-MW1, total VOC concentrations decreased from 4,900 ppb in 1988 to 2,169 ppb in 1990 to 210 ppb in January 1993. In particular, vinyl chloride decreased from 2,000 ppb in 1990 to 210 in 1993. A significant decrease also was evident in 2C-MW8, which contained 481 ppb of VOCs in 1990 and 18.3 in 1993. Both 1,1-DCA and vinyl chloride concentrations decreased considerably. In 2C-MW9, VOC concentrations increased from 1,743 ppb in 1990 to 1,976 ppb in 1993. Concentrations in 2C-MW2 and 2C-MW3 between these two high-concentration areas have been essentially stable since 1988.

Overall, analytical laboratory results and mobile laboratory results indicate consistent patterns of contamination. Differences may be explained by the depths of sampling. The hydraulic probe samples were collected from 9 to 12 feet; whereas, the monitoring wells are screened over 10-foot intervals with total depths of from 17 to 23 feet. Typically, the screened zone is from approximately 10 to 20 feet. Despite these minor variations, *in situ* sampling was an effective screening technique for identifying VOC contamination during the RFI.

Cis-1,2-DCE was the only VOC detected in the groundwater samples collected from the two deep wells. There was 1.7 ppb of cis-1,2-DCE in well 2C-MW9D. The adjacent shallow well 2C-MW9 contained 1,500 ppb of cis-1,2-DCE. The presence of cis-1,2-DCE in 1-MW9D may be caused by the downward migration of contamination from the shallow

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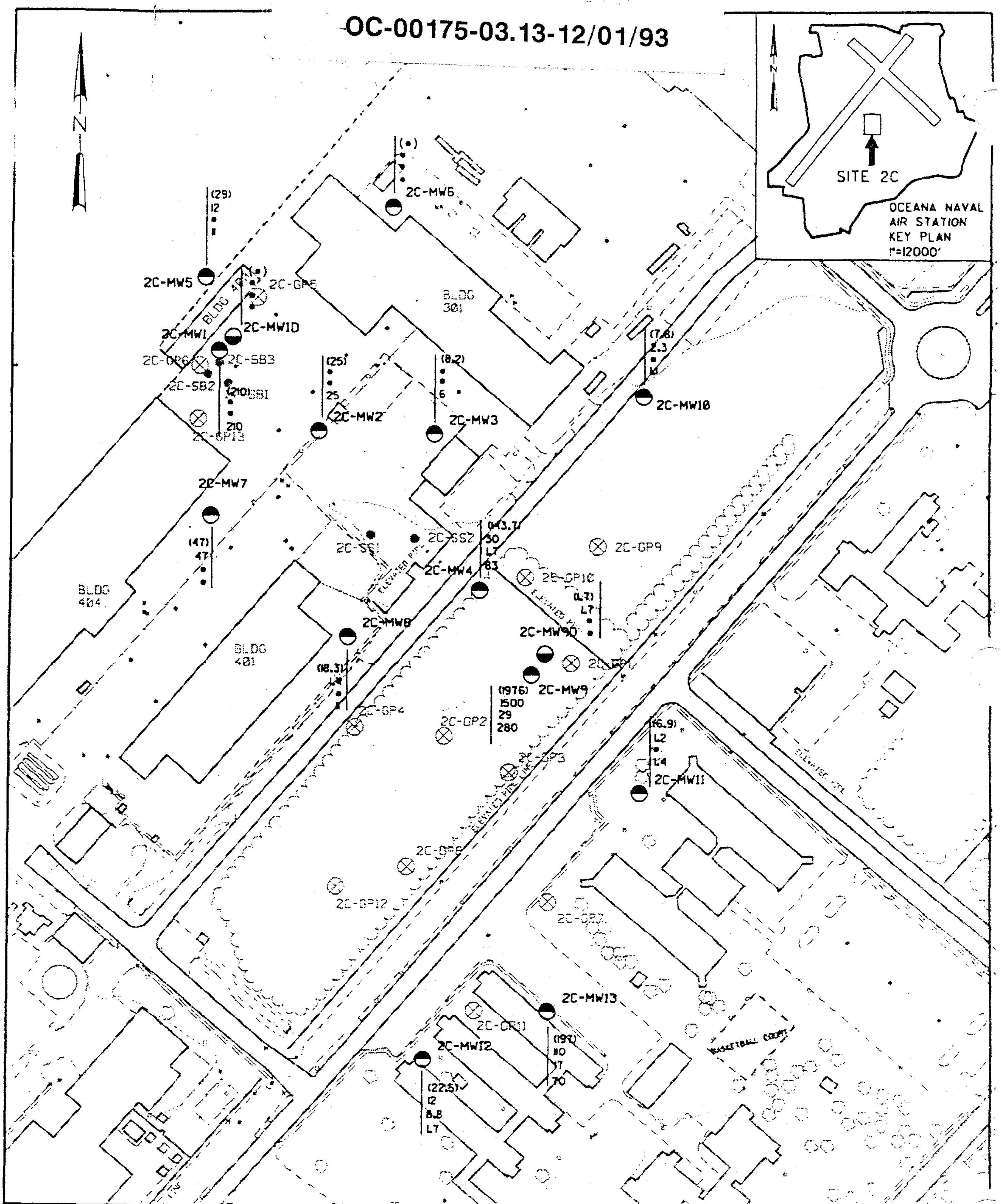

LEGEND

CONCENTRATION (ppb)
(TOTAL CHLORINATED VOCs)
CIS - 1,2 DCE
TCE
VC

SHALLOW MONITORING WELL
DEEP MONITORING WELL
NOT DETECTED
SOIL SAMPLING LOCATION
HYDRAULIC PROFILE SAMPLING LOCATION

0 100 200 300
SCALE IN FEET

Figure 4-3-4
CHLORINATED VOLATILES IN MONITORING WELLS AT SITE 2C
JANUARY 1993

CH2M HILL

sands. This migration is consistent with the slight downward gradient observed at the site. However, at such a low concentration, its presence should be confirmed before concluding that VOCs have migrated to the Yorktown.

Soils

Soil samples were collected near Line Shack 400 and in the ditch draining towards B Avenue to help evaluate probable source areas. All soil samples were analyzed for chlorinated volatiles. Three soil borings were advanced to the water table in the 2C source area and two soil samples were collected in a drainage ditch. Within the source area, samples were screened at 2-foot intervals with an OVA. Samples with the highest OVA readings were submitted for analysis. All samples were non-detects with the exception of 2C-SB3, where cis-1,2-DCE was detected at 68 ppb at a depth of 3 to 5 feet. The soil data are presented in Table 4-3-5.

Health and Environmental Assessment

The groundwater at Site 2C is contaminated with TCE, vinyl chloride, and cis-1,2-DCE above federal MCLs allowable under the Safe Drinking Water Act. Table 4-3-6 compares Site 2C contaminant concentrations against applicable federal standards.

Vinyl chloride, the most widespread of the three contaminants, was detected in eight monitoring wells. The MCL for vinyl chloride of 2 ppb was exceeded in all eight wells, at contaminant levels ranging from 11 ppb to 280 ppb. Cis-1,2-DCE exceeded the federal MCL of 70 ppb in 2C-MW9 (1,500 ppb) and in 2C-MW13 (110 ppb). Trichloroethylene exceeded the federal MCL of 5 ppb in 2C-MW9 (29 ppb), 2C-MW12 (8.8 ppb), and 2C-MW13 (17 ppb).

There are no established or proposed standards for cis-1,2-dichloroethylene in soil; however, proposed RCRA action levels in soil (EPA, 1990) for the more toxic halogenated VOCs 1,2-DCA and 1,1-DCE are 8,000 and 10,000 ppb, respectively.

Fate and Transport

The Site 2C contaminant plume is a complex combination of TCE and its degradation products, specifically vinyl chloride and cis-1,2-DCE. The composition of halogenated solvents used at Site 2C is unknown; however, TCE is a common industrial solvent that was used extensively in the past. Cis-1,2-DCE is a direct breakdown product of TCE and vinyl chloride is a product of 1,1-DCE, cis-1,2-DCE, and other dichlorinated alkanes and alkenes. All contamination could have originated as TCE or could have been introduced as a mix of solvents.

Groundwater is the principal transport mechanism at Site 2C. Ditches at the site are shallow, generally contain no water, and do not intercept groundwater as they do at

Table 4-3-5
ORGANIC COMPOUNDS IN SOILS AT SITE 2C
December 1992
(All data in $\mu g/kg$)

Analyte	Detection Limit	2C-SB1			2C-SB2		2C-SB3		2C-SS1	2C-SS2
		1-3 ft	3-5 ft		3-5 ft	5-7 ft	1-3 ft	3-5 ft	1-1.5 ft	1-1.5 ft
			Initial	Duplicate						
Chlorinated Volatile Organic Compounds										
cis-1,2-Dichloroethylene	1	*	*	*	*	*	*	68	*	*

Notes:

All compounds not reported were below detection limits in all samples.
All samples were analyzed for the 8100 chlorinated volatiles list; however, cis-1,2-dichloroethane was the only compound detected in any of the samples.
*The value was less than the instrument detection level or was not present.
QC Sampling: 2C-SB11 is a duplicate of 2C-SB1 collected from 3-5 feet.

WDCR702/036.51

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Table 4-3-6
ORGANIC CONSTITUENTS DETECTED AT SITE 2C
COMPARED AGAINST POTENTIALLY APPLICABLE FEDERAL STANDARDS
January 1993
(All data in ppb)

Compound	Location Detected	Concentration (ppb)	Health-Based Criteria for Carcinogens	Health-Based Criteria for Systemic Toxicants	MCL	MCLG	Proposed RCRA Action Level
Vinyl Chloride	2C-MW1 2C-MW2 2C-MW3 2C-MW4 2C-MW5 2C-MW8 2C-MW9 2C-MW13	210 25 6 83 11 11 280 70	NS	NS	2	0	NS
Cis-1,2-Dichloroethylene	2C-MW9 2C-MW13	1,500 110	NS	NS	70	70	NS
Trichloroethylene	2C-MW9 2C-MW12 2C-MW13	29 8.8 17	5	NS	5	0	5

Notes:
Only contaminants which were detected and exceed applicable standards are presented in the table above.
The MCL and MCLG figures are from the Drinking Water Regulations and Health Advisories, updated December 1992.
The proposed RCRA action levels were extracted from the Federal Register dated 27 July 1990.
NS - No standard available.

WDCR708/017.51

OC-00175-03.13-12/01/93

Sites 1 and 2B; therefore, surface water transport does not appear to be a significant risk. No surface water was sampled from these ditches because the ditches usually contain no water. The soil in the contaminated area near the line shack is covered in concrete. Little is known about potential soil contamination in the wooded area near 2C-MW9.

The rate of groundwater flow can be calculated from Darcy's law. On the basis of a measured hydraulic gradient of 0.002 ft/ft from 2C-MW3 to 2C-MW12, an average hydraulic conductivity of 5 x 10^{-3} cm/sec measured in 1990, and an assumed porosity of 20 percent, the linear velocity of groundwater flow is 50 feet per year. Chlorinated volatile transport is expected to be lower because of retardation. Shallow groundwater is not used anywhere on the base, so there are no known receptors of the groundwater. The boundary of the station is more than 6,000 feet from this site, so offsite receptors are not likely to be threatened.

Recommendations

The general contaminant characteristics have been characterized sufficiently to initiate a CMS of groundwater treatment alternatives for this site. Additional characterization of VOC contamination in groundwater south of London Bridge Road is essential but should not delay the review of potential remedies. Additional soil characterization near Line Stack 400 and in the woods near 2C-MW9 is also recommended. A more detailed risk analysis will be performed as part of the CMS; however, current analytical data clearly demonstrate the need for a CMS of remediation options.

Site 2D—Line Shack 125 Disposal Area

Site Location and History

Site 2D extends south-southeastward from Hanger 111 to slightly beyond Line Shack 125. The area of investigation is both inside and outside the flight line fence in the MATWING area (see Figure 4-4-1). Adjacent to the site within a wooded area at the edge of the parking lot is a shallow wetlands depression without outlet. Line Shack 125 was constructed in 1963. This site has been used since 1963 for aircraft cleaning and maintenance along with equipment and material storage. The IAS identified Site 2D as an area where waste chemicals from aircraft cleaning and maintenance activities were disposed. Potential contaminants that may have been released from 1963 until the early 1980s include: oil, hydraulic fluid, PD 680, and aromatic hydrocarbons used for lubrication, paint stripping, and grease removal.

In the early 1980s, the soil beneath Line Shack 125 was excavated and was found to be saturated with oily substances to approximately 6 feet (RGH, 1984). During construction of a new concrete pad for the line shack in the early 1980s, a bulldozer sank several feet into oil-saturated soil after the asphalt had been scraped away (RGH, 1984). Approximately 6 feet of oil-saturated soil was excavated before the new concrete pad was poured. The IAS also reported that waste liquids were formerly disposed in low areas behind Line Shack 125 (RGH, 1984). This disposal area was shown in the IAS report to be within 40 feet of the northwest side of Line Shack 125 (RGH, 1984) and is illustrated in Figure 4-4-1.

Past Investigations and RFI Site Activities

This and other line shack sites were identified as locations requiring further study in the IAS in 1984. The Interim RFI activities at Site 2D in 1990 were the only other previous investigation activities at this site. The Interim RFI's results indicate only one of three monitoring wells at Site 2D had detectable amounts of contamination. Specifically, groundwater collected at 2D-MW2 contained 1,1-DCE. As a result, the purpose of the RFI site activities at Site 2D was to obtain a second round of groundwater data from previously sampled wells to determine if further investigation is required. The data from the Interim RFI were insufficient to support installation of additional wells or to initiate soil sampling in an effort to identify the potential source of the contaminant in one well. CH2M HILL personnel resampled the three monitoring wells at Site 2D as part of the RFI field investigation. Well 2D-MW2 was analyzed for volatiles and semivolatiles. The other two wells were analyzed for volatiles and PAHs. Well 2D-MW1 was resurveyed during the RFI because since the 1990 Interim RFI the casing had been cut down to allow for parking lot construction. Data on the monitoring system is shown in Table 4-4-1.

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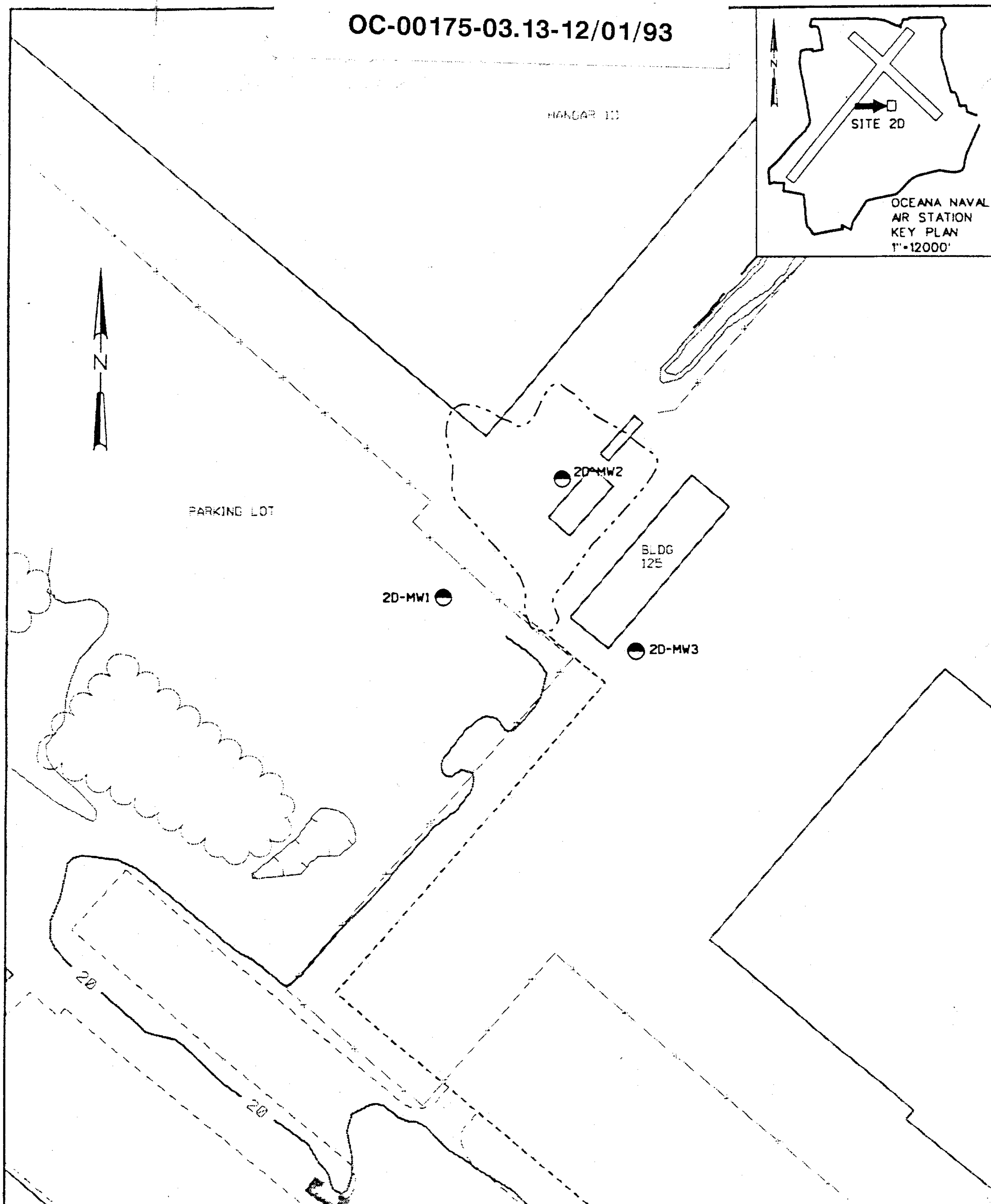

LEGEND

- SHALLOW MONITORING WELLS
- APPROXIMATE OIL DISPOSAL AREA INDICATED IN THE IAS REPORT (RGH, 1984)

0 100 200 300

SCALE IN FEET

Figure 4-4-1

RFI SAMPLING LOCATIONS
AT SITE 2D
JANUARY, 1993

CH2M HILL

Table 4-4-1
SITE 2D MONITORING WELL SUMMARY

Well Number	Date Installed	Ground Elevation (feet above MSL)	Total Depth (feet)	Screened Interval (feet below ground surface)
2D-MW1	06/28/90	21.52*	17	7-17
2D-MW2	07/02/90	22.3	19	9-19
2D-MW3	07/03/90	22.1	19	9-19

Note:
*Since the last round of surveying in 1990, 2D-MW1 has been changed from a monitoring well with protective casing to a flush mount. 2D-MW1 is now located in a parking lot which has been graded. The former ground elevation was 18.9 feet. The ground elevation is now 21.52 feet.

Environmental Setting

The study area includes asphalt areas on the flight line, a parking lot outside the flight line, a small emergent wetland, and a wooded area immediately west of the parking lot. Much of the area is in the flight line, which is covered with impervious surfaces. The wooded area occurs off the flight line. Parts of the wooded area appear to have undergone recent disturbances because of the presence of earthen berms, construction, and vegetative debris. The site slopes slightly to the west toward the wooded area. The environmental setting of Site 2D is shown in Figure 4-2-2.

Ecology

Surface Water Resources. Except for the ponded wetland, water resources in this area are limited to a short ditch, which occurs in the southeastern corner of the wooded area that drains southwest. The ditch continues through a culvert and under 1st Street. Very little flow was observed in this portion of the ditch, and no signs of contamination were observed. The water in the ponded wetland was fairly clear and had no visible signs of contamination.

Wetlands. A small oval-shaped, emergent wetland, approximately 20 feet in diameter, occurs in the southeast corner of the site. The wetland seems to have developed from ponded surface flows that are directed from the northeast into the depression via a culverted pipeline. No outlet was seen; however, it appears that high flows may spill over and flow through the wooded area into another ditch. The depth of water in the wetland at the time of the survey was approximately 8 inches.

Vegetation. The vegetation in the ponded wetland includes cattail, soft rush, water purslane, spike rush, and water plantain. Most of the vegetation is growing on the slopes of the depression. Open-water habitat occurs over more than 50 percent of the surface area of the wetland. With the exception of the wooded area, lawn grasses occur over most of the unpaved portion of the site. The overstory in the wooded area is sparse and is dominated by sweetgum, southern red oak, and red maple. The understory is dominated by greenbriar, giant cane, and Japanese honeysuckle.

Except for a small, recently cleared area, no evidence of vegetative stress was observed in the area.

Wildlife. No wildlife or birds were observed at this location. However, the wooded area provides suitable habitat for roosting, and possibly nesting, for birds that are adapted to living in more developed areas. The wetland area is very small and isolated, however it may provide valuable habitat to small mammals, amphibians, and reptiles because similar habitat is all but absent in the immediate vicinity.

Geologic and Hydrogeologic Characteristics

The borehole logs from the Interim RFI indicate that the local subsurface sediments consist of clay, sandy silt, and silty sand to a depth of 19 feet. The clean sand, which at other sites typically underlies the sediments listed above, was not encountered at this site.

The water-level measurements collected at Site 2D as part of the RFI in January 1993 are presented in Table 4-4-2. Figure 4-4-2 shows the equipotential contour lines in the shallow Columbia Group aquifer. The groundwater flow direction is difficult to define with only three wells but appears to be to the west-northwest.

Table 4-4-2
SITE 2D WATER-LEVEL DATA
JANUARY 1993

Well	Depth to Water (Feet Below Survey Datum)	Water-Level Elevation (Feet Above Mean Sea Level)
2D-MW1	4.87	16.65
2D-MW2	5.52	16.74
2D-MW3	4.82	17.28

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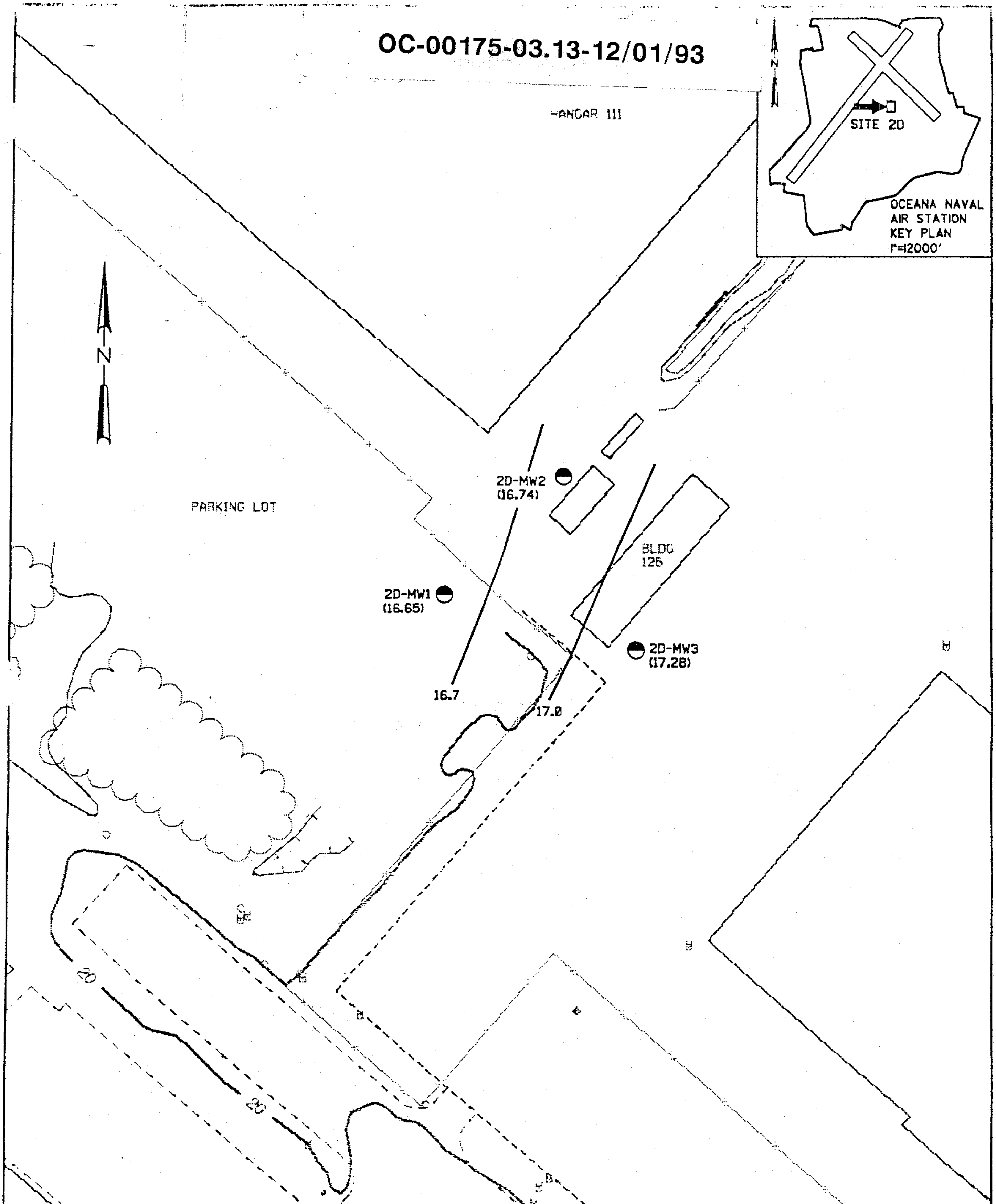

LEGEND

- SHALLOW MONITORING WELLS
- ( ) WATER LEVEL ELEVATIONS
- EQUIPOTENTIAL LINES

0 100 200 300
SCALE IN FEET

Figure 4-4-2
WATER LEVEL ELEVATIONS
AND EQUIPOTENTIAL CONTOURS
AT SITE 2D
JANUARY 1993

CH2M HILL

9368k2d2.dgn
26-Apr-1993

Contamination and Extent

The analytical results from the groundwater sampling during the Site 2D RFI confirmed the Interim RFI groundwater sampling results. These data are listed in Table 4-4-3. 1,1-DCA was detected at 56 ppb and 1,1-DCE was detected at 12 ppb in the sample collected from 2D-MW2 during the January 1993 RFI sampling. These results confirmed the August 1990 results of 64 ppb and 9 ppb, respectively. Three other volatile organic compounds at low concentrations detected in 1990 in 2D-MW2 were absent in the RFI sampling event. Polynuclear aromatics were not detected in any Site 2D groundwater samples. One semivolatile compound, di-n-butylphthalate, was detected in 2D-MW2 at 2 ppb, which was below the quantitative detection limit. Di-n-butylphthalate is a common laboratory contaminant that may not be present in the environment.

Health and Environmental Assessment

Of the compounds detected at Site 2D, 1,1-DCE was the only one that exceeded any health-based criteria. 1,1-DCE was detected in 2D-MW2 at a concentration of 12 ppb, slightly above the 7 ppb MCL.

Fate and Transport

Because the area near 2D-MW2 is covered with asphalt, the primary transport mechanism of contamination in both the saturated and unsaturated zones in this area is groundwater. Because groundwater flow appears to be to the west-northwest, contaminated groundwater is expected to flow beneath the new parking lot towards the small wooded area that forms the southwest border of the parking lot. No ditches or depressions in this area are believed to be low enough to receive groundwater discharge. No data on *in situ* hydraulic conductivity at Site 2D have been collected; however, because of the higher silt content of the Columbia Aquifer at this site, the average linear velocity is expected to be less than the 50 ft/year at Site 2C. Vinyl chloride, the most common breakdown product of 1,1-DCE, was not detected in the monitoring wells.

Recommendations

Because the RFI results confirm that groundwater in 2D-MW2 is contaminated above standards, it is important to characterize the extent of volatile groundwater contamination at Site 2D more completely. The current data show that contamination in 2D-MW2 is highest but the distribution of the plume west and north of 2D-MW2 is unknown. To determine the extent of contamination, the continuation of the RFI is warranted, including a program of soil sampling, *in situ* groundwater sampling, and installation and sampling of shallow wells on the basis of the *in situ* results.

Table 4-4-3
ORGANIC COMPOUNDS IN GROUNDWATER AT SITE 2D
RESULTS OF RFI AND PREVIOUS INVESTIGATION
(All Data in ppb)

Analyte	Detection Limit	2D-MW1		2D-MW2		2D-MW3		
		8/90	1/93	8/90	1/93	8/90	1/93 Initial	1/93 Duplicate
EDB	0.02	*	NA	*	NA	*	NA	NA
TPH	60	360	NA	220	NA	*	NA	NA
Volatile Organic Compounds								
Acetone	10	5 bj	5 bj	5 bj	8 j	20 b	4 j	6 j
Benzene	5	*	*	3 j	2 j	*	1 j	*
Carbon disulfide	5	*	*	*	*	1 j	*	*
1,1-Dichloroethane	5	*	*	64	56	*	*	*
1,1-Dichloroethylene	5	*	*	9	12	*	*	*
1,2-Dichloroethylene (total)	5	*	*	2 j	*	*	*	*
Ethylbenzene	5	*	*	2 j	*	*	*	*
Methylene chloride	5	4 bj	5 b	3 bj	3 bj	4 bj	2 bj	5 b
Xylenes (total)	5	*	*	6	*	*	*	*
Chloroethane	10	*	*	*	5 j	*	*	*
Semivolatile Organic Compounds								
Di-n-Butylphthalate	10	NA	NA	NA	2 j	NA	NA	NA
Polynuclear Aromatics (PAHs)	2	NA	*	NA	A	NA	*	*

Notes:
EDB Ethylene Dibromide
TPH Total Petroleum Hydrocarbons
NA Not analyzed
(*) Concentration below detection limit
A PAH compounds were analyzed as part of the semivolatile analysis
b Compound found in laboratory blank as well as sample
j Estimated value; measured value is less than the accurately quantitative detection limit

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The elevation of the bottom of the wetlands depression will be surveyed to determine if groundwater discharge to the wetlands is possible; however, preliminary observations suggest that the depression is too high to be a groundwater discharge point. Pending the surveying results, no surface water sampling is recommended.

Site 2E—Line Shack 109 Disposal Area

Site Location and History

Site 2E is the area bounded by Hangar 23, Line Shack 109, Building 110, and a steam line along First Street (see Figure 4-5-1). Because Line Shack 109 was constructed in 1963, it has been used for cleaning and maintaining aircraft and storing equipment and material. The IAS identified this site as a location where waste chemicals from the Navy's cleaning and maintenance activities were disposed (RGH, 1984). These wastes potentially include oil, PD 680, aromatic hydrocarbons, and hydraulic fluid (RGH, 1984). An area for disposing of petroleum, oil, and lubricant was reportedly behind Line Shack 109 along the flight line fence (RGH, 1984). At the time of the IAS, a waste oil bowser and hazardous waste drums were seen on the ground along the fence (RGH, 1984). Waste oil also was reportedly funneled into an electric manhole near Line Shack 109 (RGH, 1984). This practice damaged some electrical circuits, which prompted a cleanup of the manhole affected by the waste oil. During a 1993 inspection of manholes at the site, two manholes near the south corner of Hangar 23 were found to be smeared with oil and may be where oil was disposed. No manholes exist near well 2E-MW1. A temporary hazardous waste storage area was constructed next to the fence near Hangar 23 between 1984 and 1988.

Past Investigations and RFI Site Activities

Line Shack 109 was recommended for further investigation in the 1984 IAS and was later reviewed during the RFA in 1988. Site 2E represents the combination of RFA SWMU 51, the line shack, and RFA SWMU 1, the hazardous waste storage area. The two sites were investigated together during the Interim RFI in 1990. Three wells were installed and sampled and four soil samples were collected. Because the storage unit is in the line shack area, for the purposes of the RFI, the two sites were combined to form Site 2E. The groundwater sampling results from the Interim RFI indicated that the parameters analyzed were either not detected or were detected at levels below the accurately quantifiable level. The same result was true of the soil data, with the exception of TPH, which was detected in two soil samples (2E-SS2 and 2E-SS3) at concentrations of 513 and 242 ppm, respectively. The site monitoring wells are summarized in Table 4-5-1.

The purpose of the RFI activities at Site 2E was to obtain a second round of groundwater data to determine if further investigation is required and to determine the extent of TPH contamination in the soil.

The RFI field investigation consisted of the resampling of groundwater from 2E-MW1, 2E-MW2, and 2E-MW3 and interactive soil sampling at 6 locations. CH2M HILL personnel collected six soil samples (2E-SS5 through 2E-SS10) at the locations shown in Figure 4-5-1. Samples were collected from 0.5 to 1.0 feet at all locations. At the

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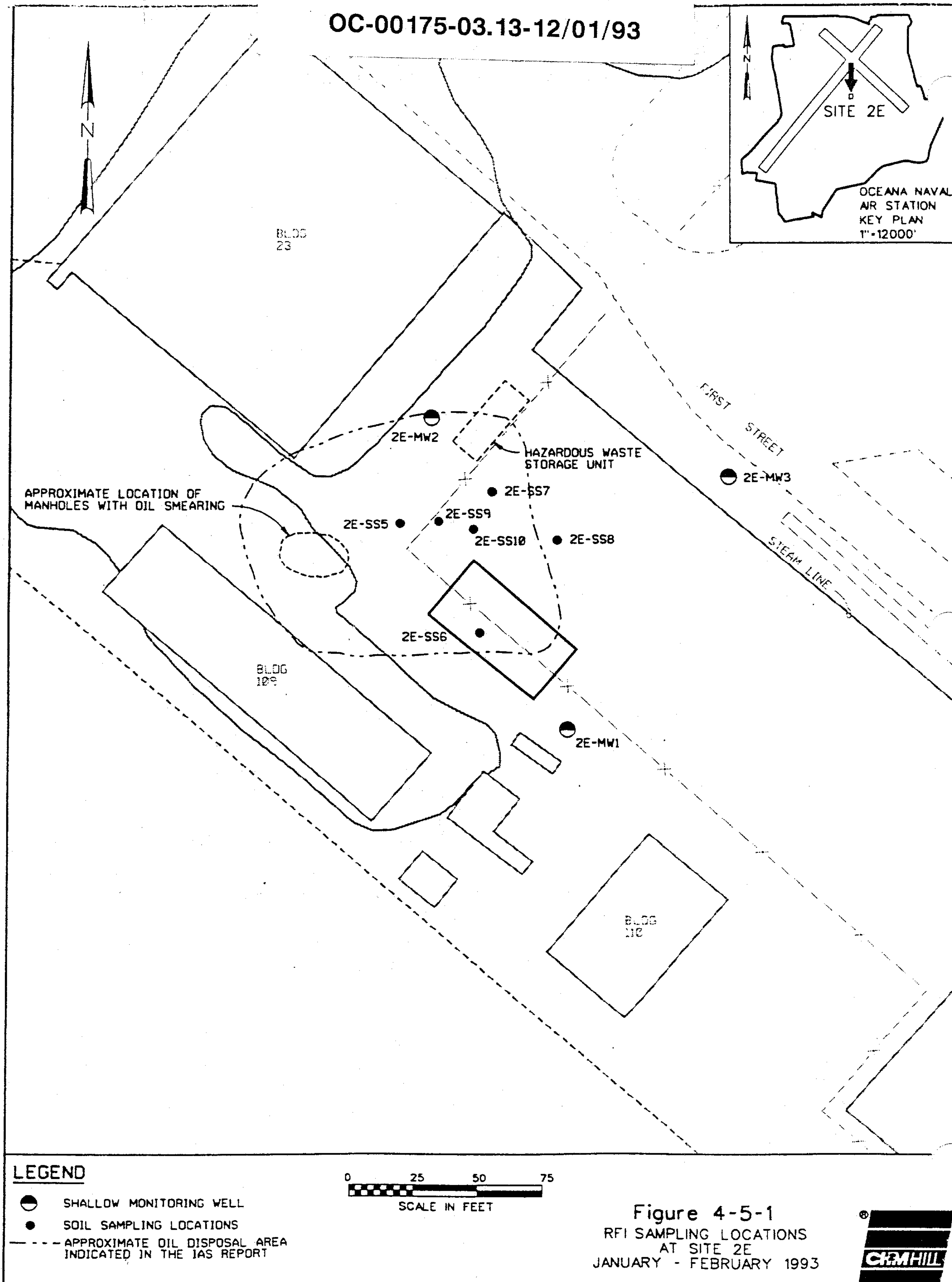

Figure 4-5-1
RFI SAMPLING LOCATIONS
AT SITE 2E
JANUARY - FEBRUARY 1993

0368k2e4.dgn

Table 4-5-1
SITE 2E MONITORING WELL SUMMARY

Well Number	Date Installed	Ground Elevation (feet above MSL)	Total Depth (feet)	Screened Interval (feet below ground surface)
2E-MW1	06/28/90	20.3	19	9-19
2E-MW2	07/06/90	19.4	18	8-18
2E-MW3	07/02/90	18.9	18	8-18

locations that appeared most contaminated (2E-SS5 and 2E-SS9), additional samples were collected from 2.0 to 3.0 feet. Some pre-CMS samples also were collected at 2E-SS6, 2E-SS8, and 2E-SS10.

Most soil and groundwater samples collected at Site 2E were analyzed for VOCs, PAHs, and total metals. In addition, TPH analysis was performed on the soil samples, and semivolatile organic compounds (SVOCs) were substituted for PAHs in samples from 2E-SS6 and 2E-MW1.

Environmental Setting

The study area includes a parking lot west and south of Line Shack 109 and an area of lawn between First Street and the line shacks. About half of the site is in the flight line. The developed areas are either covered in asphalt or have been planted with turf grasses and maintained as lawn. The area off the flight line is a maintained lawn. The northeastern boundary of the site is traversed by a steam line that runs generally northwest/southeast along First Street.

Ecology

Runoff from the paved surfaces near Building 109 flows onto the lawn and enters a drainage swale that was observed in the southeastern part of the site. The swale apparently connects surface flows to a small ditch adjacent to the access road. The swale was slightly ponded at the time of the survey.

No wetlands occur in the Site 2E study area. Turf grasses, a few cultivated Bradford pear trees, and three sweetgum trees are the only vegetation at this site. No wildlife was observed in the area.

Geologic and Hydrogeologic Characteristics

Shallow boreholes drilled at this site as part of the Interim RFI indicate that the subsurface stratigraphy generally consists of two sedimentary units. A unit of fine silts and clays approximately 7 to 8 feet thick is underlain by a layer of clean and silty sand that extends to a depth of at least 20 feet. Both units are part of the Columbia Group sediments described in Chapter 2.

Table 4-5-2 lists the water-level measurements recorded in the field in January 1993. Figure 4-5-2 shows the water-level elevation in each well. The presence of free product in 2E-MW1 depressed the natural water level so the measured water level is a poor indicator of the groundwater potential in this well. Because there are only two other measurement points, the equipotential contour lines in the shallow aquifer in January 1993 are not shown. However, during the Interim RFI in 1990 free product was not present in 2E-MW1 and it was determined that groundwater flowed to the southwest.

Table 4-5-2
SITE 2E WATER-LEVEL DATA
JANUARY 1993

Well	Depth to Water (Feet Below Survey Datum)		Water-Level Elevations (Feet Above Mean Sea Level)	
2E-MW1	12.42	(4.98)*	10.1	(17.5)*
2E-MW2	2.77		16.66	
2E-MW3	4.09		16.74	

*Indicates free product level. The hydrocarbons in well 2E-MW1 have depressed the natural water level.

Contamination and Extent

The analytical laboratory results of soil and groundwater samples at Site 2E are presented in Tables 4-5-3 through 4-5-6.

Groundwater

The RFI groundwater sampling confirmed the absence of the organic contaminants in 2E-MW2 and 2E-MW3 that was noted during the Interim RFI; however, while collecting water-level measurements from the monitoring wells in January 1993, CH2M HILL field

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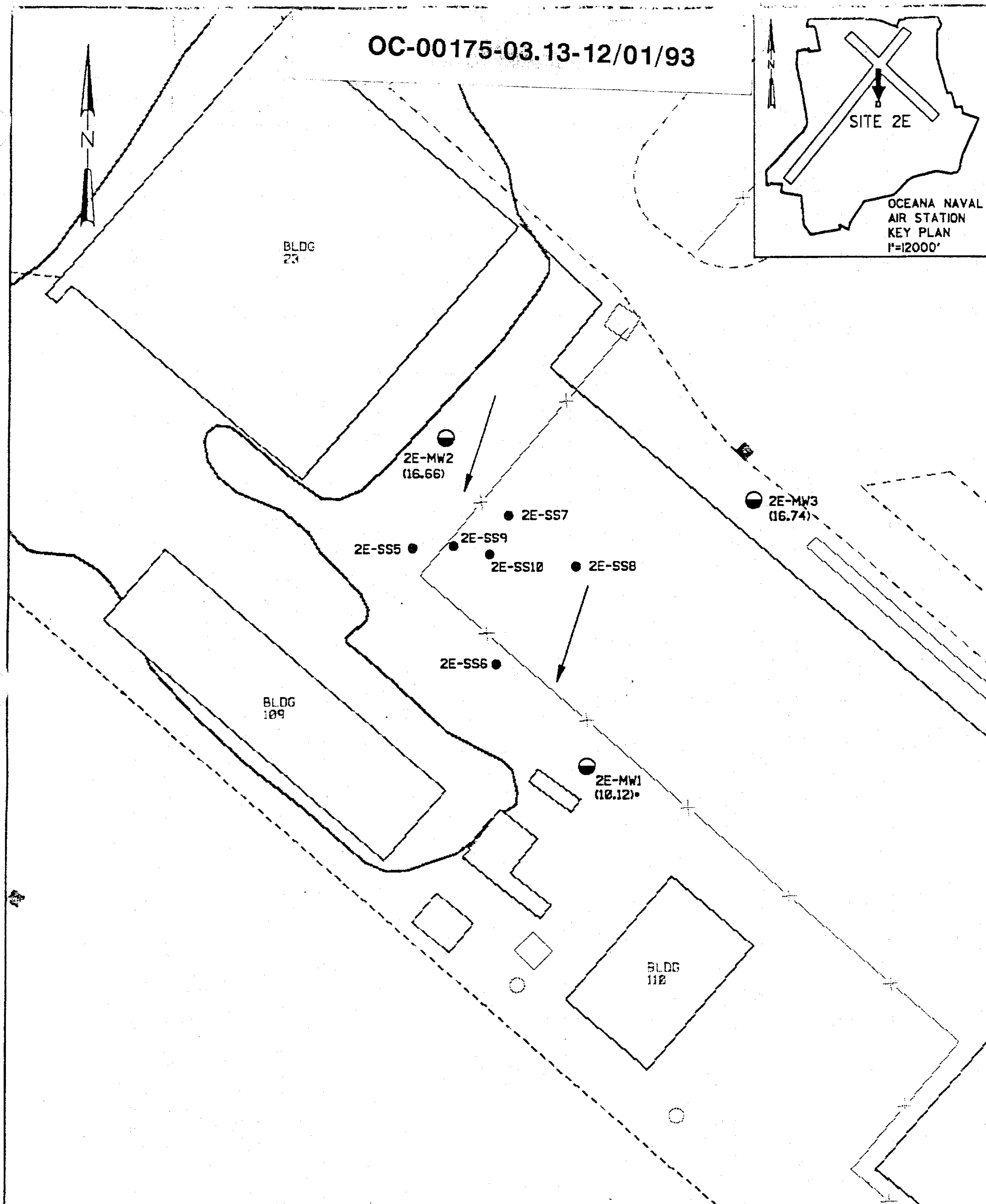

LEGEND

- SHALLOW MONITORING WELL
- SOIL SAMPLING LOCATIONS
- ( ) WATER LEVEL ELEVATIONS
- • FREE PRODUCT WELL
- ← DIRECTION OF GROUNDWATER FLOW IN 1990

0 25 50 75
SCALE IN FEET

Figure 4-5-2
WATER LEVEL ELEVATIONS
AT SITE 2E
JANUARY 18, 1993

CH2M HILL

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13-Jun-1993

Table 4-5-3
ORGANIC COMPOUNDS IN GROUNDWATER AT SITE 2E
RESULTS OF RFI AND INTERIM RFI
(Concentrations in ppb)

Analyte	Detection Limit	2E-MW1[a]			2E-MW2		2E-MW3	
		August 1990	January 1993 Initial	January 1993 Duplicate	August 1990	January 1993	August 1990	January 1993
TPH	60	200	NA	NA	*	NA	210	NA
EDB	0.02	*	NA	NA	*	NA	*	NA
Volatile Organic Compounds								
Acetone	10	6 b,j	40 j	NA	6 b,j	10 b	4 b,j	*
Benzene	5	2 j	8 j	NA	*	*	*	*
Carbon disulfide	5	*	*	NA	*	*	2 j	*
Ethylbenzene	5	2 j	54	NA	*	*	*	*
Methylene chloride	5	5 b	14 j	NA	7 b	3 b,j	5 b	3 b,j
Xylenes (total)	5	3 j	62	NA	*	*	*	*
Semivolatile Organic Compounds								
Naphthalene	10	NA	9,400 e	3,000	NA	NA	NA	NA
2-Methylnaphthalene	10	NA	38,000 e	12,000 e	NA	NA	NA	NA
Fluorene	10	NA	3,400	1,200	NA	NA	NA	NA
Phenanthrene	10	NA	5,900	2,200	NA	NA	NA	NA
Anthracene	10	NA	410	120 j	NA	NA	NA	NA
Pyrene	10	NA	330	98 j	NA	NA	NA	NA
Acenaphthylene	10	NA	*	500	NA	NA	NA	NA
Polynuclear Aromatics	2	NA	NA	NA	NA	*	NA	*

Notes: All volatile, semivolatile, and polynuclear aromatic compounds not listed above were analyzed, but not detected. At 2E-MW1, the semivolatiles analysis encompasses the polynuclear aromatic analysis.

EDB = Ethylene dibromide
TPH = Total petroleum hydrocarbons
PNA = Polynuclear aromatics (PAHs)
(*) = Concentration below detection limit
b = Compound found in laboratory blank as well as in sample
j = Estimated value
e = Compound concentration exceeds calibration range.
NA = Not analyzed

[a]In January 1993, the field duplicate SVOC results were in poor correlation with the initial sample SVOC results as determined by the data validation process. No qualification was performed.

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[illegible]-5-4

INORGANIC COMPOUNDS IN GROUNDWATER AT SITE 2E
January 1993 to February 1993
(Concentrations in $\mu g/l$)

	2E-MW1			2E-MW2		2E-MW3	
	Initial		Duplicate				
Analyte	Total	Dissolved	Total	Total	Dissolved	Total	Dissolved
Aluminum	1,830 +	53.4 b	1,290 +	435	41.6 b	230	212
Antimony	<16.4	<16.4	<16.4	<16.4	<16.4	<16.4	<16.4
Arsenic	7.3 n	2.0 b	6.2 b,n	2.9 b	2.0 b	3.3 b	1.5 b
Barium	23 b	15.8 b	19.8 b	23.5 b	19.8 b	13.8 b	14.4 b
Beryllium	<0.26	<0.26	<0.26	<0.26	<0.26	<0.26	<0.26
Cadmium	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8
Calcium	14,200	16,100	14,300	12,200	11,700	7,430	7,120
Chromium	5.1 b	<2.8	4.4 b	<2.8	<2.8	3.1	<2.8
Cobalt	<2.6	<2.6	<2.6	3.6 b	3.3 b	2.7 b	<2.6
Copper	7.7 b	4.3 b	6.7 b	<1.2	<1.2	<1.2	<1.2
Iron	19,100 +	9,670	19,100 +	14,400	11,500	4,090	1,750
Lead	2.2 b,n	<1.7	2.8 b,w,n	21.7	<1.7	4.0	<1.7
Magnesium	23,400	24,200	23,500	19,400	19,200	8,930	8,780
Manganese	1,560	1,590	1,570	622	612	298	294
Mercury	<0.07	<0.14	<0.07	0.12 b	0.10 b	0.15 b	0.08 b
Nickel	13.0 b	<9.4	16.2 b	12.6 b	10 b	<9.4	<9.4
Potassium	1,200 b	982 b	1,070 b	<934	<934	<934	<934
Selenium	<1.8	<1.8	2.7 b,w,n	<1.8	<1.8	<1.8	<1.8
Silver	<2.0 n	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Sodium	14,600	15,000	14,000	11,700	11,800	14,900	15,500
Thallium	<2.3	<2.3	<2.3	<2.3	<2.3	<2.3	<2.3
Vanadium	5.0 b	<2.6	3.8 b	2.7 b	<2.6	<2.6	<2.6
Zinc	30.4	33.3	34.1	61.7	101	31.8	28.5

Notes: < = Value less than IDL or was not detected.
b = Value less than the CRDL, but greater than or equal to the IDL.
w = Post digestion spike for furnace AA analysis is out of control limits, while sample absorbance is less than 50 percent of spike absorbance.
n = Spiked sample recovery not within control limits.
QC sampling: 2E-MW30 is a duplicate of 2E-MW1; however, no dissolved metals analysis was performed on 2E-MW30.
+ = Duplicate analysis not within control limits

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Table 4-5-5
ORGANIC COMPOUNDS IN SOILS AT SITE 2E
RESULTS OF RFI AND INTERIM RFI
(All data in μg/kg)

Analyte	2E-SS1	2E-SS2	2E-SS3	2E-SS4	2E-SS5		2E-SS6		2E-SS7	2E-SS8	2E-SS9
	8/90	8/90	8/90	8/90	1/93		2/93		1/93	1/93	2/93
					0.5-1.0 ft.	2-3 ft.	Initial 0.5-1.0 ft.	Duplicate 0.5-1.0 ft.	0.5-1.0 ft.	0.5-1.0 ft.	2.0-3.0 ft.
TPH	99,400	513,000	242,000	NA	607,000	64,500	189,000	77,400	26,500	286,000	10,800
EDB	*	*	*	NA	NA	NA	NA	NA	NA	NA	NA
Volatile Organic Compounds											
Acetone	11 bj	21 b	13 b	14 b	56 b	20 b	10 j	5 j	17 b	12 b	86 b
Methylene chloride	24 b	13 b	61 b	120 e	9 b	7 b	4 bj	4 bj	8 b	10 b	9 b
Toluene	*	*	*	2 j	*	*	*	*	*	*	*
2-Butanone	*	*	*	*	13	*	*	*	*	*	14
Xylene (total)	*	*	*	*	*	21	*	*	*	3 j	6 j
Semivolatile Organic Compounds											
Di-n-butylphthalate	NA	NA	NA	NA	NA	NA	170 bj	57 bj	NA	NA	NA
bis(2-ethylhexyl)phthalate	NA	NA	NA	NA	NA	NA	43 j	*	NA	NA	NA
Polynuclear Aromatics											
Acenaphthene	NA	NA	NA	NA	*	35 j	*	*	*	*	*
Fluorene	NA	NA	NA	NA	*	30 j	*	*	*	*	*
Phenanthrene	NA	NA	NA	NA	*	96	*	*	110	*	*
Fluoranthene	NA	NA	NA	NA	*	64	*	*	100	43 j	*

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Table 4-5-5
ORGANIC COMPOUNDS IN SOILS AT SITE 2E
RESULTS OF RFI AND INTERIM RFI
(All data in μg/kg)

Analyte	2E-SS1	2E-SS2	2E-SS3	2E-SS4	2E-SS5		2E-SS6		2E-SS7	2E-SS8	2E-SS9
	8/90	8/90	8/90	8/90	1/93		2/93		1/93	1/93	2/93
					0.5-1.0 ft.	2-3 ft.	Initial 0.5-1.0 ft.	Duplicate 0.5-1.0 ft.	0.5-1.0 ft.	0.5-1.0 ft.	2.0-3.0 f
Pyrene	NA	NA	NA	NA	*	43 j	*	*	120	*	*
Benzo(a)Anthracene	NA	NA	NA	NA	*	*	*	*	54 j	*	*
Chrysene	NA	NA	NA	NA	*	*	*	*	75	*	*
Benzo(b)Fluoranthene	NA	NA	NA	NA	*	*	*	*	110	*	*
Benzo(k)Fluoranthene	NA	NA	NA	NA	*	*	*	*	110	*	*
Benzo(a)Pyrene	NA	NA	NA	NA	*	*	*	*	98	*	*
Indeno(1,2,3-CD)Pyrene	NA	NA	NA	NA	*	*	*	*	110	*	*
Benzo(g,h,i)Perylene	NA	NA	NA	NA	*	*	*	*	73	*	*

Notes:
QC sampling: 2E-SS30 is a duplicate of 2E-SS6.
NA Not analyzed
EDB Ethylene Dibromide
TPH Total Petroleum Hydrocarbons
(*) Concentration analyzed but not detected
a Detection limit range in soil for TPH samples particular to this site.
b Compound found in laboratory blank as well as sample. Sample concentration is less than 10 times blank concentration.
e Compound found in laboratory blank as well as sample. Sample concentration is greater than 10 times blank concentration.
j Estimated value. Measured value is less than the quantitative detection limit.

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Table 4-5-6
INORGANIC COMPOUNDS IN SOILS AT SITE 2E
January 1993 to February 1993
(All data in ppm)

Analyte	2E-SS5 0.5-1.0 ft	2E-SS5 2.0-3.0 ft	2E-SS6 Initial 0.5-1.0 ft	2E-SS6 Duplicate 0.5-1.0 ft	2E-SS7 0.5-1.0 ft	2E-SS8 0.5-1.0 ft	2E-SS9* 2.0-3.0 ft
Aluminum	6,880	7,670	4,930	3,820	8,910	12,500	16,900
Antimony	<3.6	<3.8	<3.6 n	<3.7 n	<3.8	<3.9	<4.6
Arsenic	1.8 b	2.0 b	1.1 b	1.1 b	1.9 b	2.7	2.0 b
Barium	50.1	35.9 b	22.2 b	14.0 b	44.7 b	60.3	93.4
Beryllium	0.32 b	0.34 b	0.15 b	0.10 b	0.43 b	0.52 b	0.57 b
Cadmium	1.5	<0.65	<0.61	<0.61	3.5	6.6	<0.78
Calcium	1,240	912 b	508 b	349 b	2,510	1,460	883 b
Chromium	11.4	11.9	6.0	4.2	20.5	21.5	19.3
Cobalt	2.6 b	2.0 b	1.2 b	0.78 b	2.9 b	3.6 b	3.1 b
Copper	31.2	6.2	4.5 b	4.2 b	41.1	58.0	7.3
Iron	5,220	4,460	3,810 +	3,430	6,710	8,340	6,380
Lead	13.5	25.2	4.2	5.3 +	53.9	26.2	12.4
Magnesium	769 b	606 b	243 b	230 b	751 b	944 b	1,080 b
Manganese	33.5	23.5	12.4	11.7	51.2	64.5	24.5
Mercury	0.04 b	0.05 b	<0.03	<0.04	0.06 b	0.07 b	0.11 b
Nickel	6.7 b	5.4 b	<2.1	<2.1	7.2 b	9.2 b	11.5
Potassium	502 b	445 b	<206	<208	446 b	526 b	444 b
Selenium	<0.4	<0.43	<0.41	<0.41	<0.42	<0.44	<0.52
Silver	0.67 b	<0.47	<0.44	<0.44	<0.46	<0.48	<0.57
Sodium	226 b	252 b	159 b	161 b	291 b	276 b	338 b
Thallium	<0.51	<0.54	<0.51	<0.52	<0.53	<0.56	<0.66
Vanadium	12.9	13.0	8.0 b	5.5 b	16.0	22.7	18.5
Zinc	35.2	21.5	8.7	10.2	105	74.0	22.4

Notes:
*The nondetect results of antimony were rejected during the data validation process because the spike recovery was less than 30 percent.
QC = 2E-SS30 is a duplicate of 2E-SS6.
b = The reported value was less than the CRDL but greater than or equal to the IDL.
< = The constituent was not detected at this instrument detection limit.
n = Spiked sample recovery not within control limits.
(+) = Duplicate analysis not within control limits.

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personnel discovered a 7-foot-thick layer of free product in 2E-MW1. This free product was not present at the time of Interim RFI sampling in August 1990. On the basis of its odor, the free product was judged to be diesel fuel.

Specifically, the volatile groundwater contaminants detected in 2E-MW1 were the common fuel-related VOCs benzene, ethylbenzene, and xylenes. High concentrations of several semivolatiles related to fuel also were detected in 2E-MW1. These compounds are listed in Table 4-5-3.

Several heavy metals were detected at concentrations near their detection limits during the RFI groundwater sampling. These concentrations were similar to concentrations in groundwater at other sites and do not appear to be a problem. Table 4-5-4 summarizes the inorganic results.

Soils

One goal of the Site 2E field activities was to characterize the TPH contamination at Site 2E more completely. TPH was detected in every soil sample submitted for TPH analysis. The highest concentrations in the shallow soil samples were from 0.5 to 1.0 foot. For instance, 2E-SS5 and 2E-SS8 contained 607 ppm and 286 ppm, respectively, and 2E-SS6 contained 189 ppm. The organics and TPH data are summarized in Table 4-5-5 in units of ppb (μg/kg).

Two VOCs were detected in the Site 2E soils at low concentrations. 2-butanone was present at a depth of 0.5 to 1 foot in 2E-SS5 (13 ppb) and 2E-SS9 (14 ppb) and xylene was detected at a depth of 2.0-3.0 feet in three locations: at 2E-SS5 (21 ppb), 2E-SS8 (3 ppb), and 2E-SS9 (6 ppb). The xylene concentrations in the latter two samples were detected below the quantitative detection limit.

Two semivolatiles were estimated below quantitative detection limits in 2E-SS6, the only soil analyzed for semivolatiles. Five PAH compounds were detected in 2E-SS5, 10 PAH compounds were detected in 2E-SS7, and an estimated concentration (43 ppb) of fluoranthene was detected in 2E-SS8.

Several heavy metals were detected in the Site 2E soils, including: arsenic, barium, beryllium, chromium, cobalt, copper, lead, vanadium, and zinc. Heavy metal concentrations were low, in most cases near or below the quantitative detection limit.

Health and Environmental Assessment

The sampling results from Site 2E were compared against applicable standards to determine if the contaminant concentrations posed a threat to human health or the environment. This information is presented in Table 4-5-7.

Table 4-5-7
CONSTITUENTS IN SITE 2E GROUNDWATER AND SOILS THAT EXCEEDED POTENTIALLY APPLICABLE FEDERAL AND VIRGINIA STANDARDS
February 1993
(All data in ppb)

Groundwater

Compound	Location Detected	Concentration (ppb)	MCL	MCLG	Virginia Groundwater Standards
Mercury	2E-MW3 Total Dissolved 2E-MW3 Total Dissolved	 0.12 b 0.10 b 0.15 b 0.08 b	2	2	.05
Zinc	2E-MW2 Total Dissolved	 61.7 101	--	--	50

Soil

Compound	Location Detected	Concentration (ppb)	Health Based Criteria for Carcinogens	Health Based Criteria for Systemic Toxicants	Proposed RCRA Action Levels	Virginia Soil Guidance Limit	Eastern United States Soil Mean
Beryllium	2E-SS5 2E-SS6 2E-SS7 2E-SS8 2E-SS9	320, 340 a 150 430 520 570	143	400	200	NS	550
Total Petroleum Hydrocarbons (TPH)	2E-SS5 2E-SS6 2E-SS8	607,000 189,000 286,000	NS	NS	NS	100,000	NA
Benzo(a)pyrene	2E-SS7	98	60.9	NS	NS	NS	NA

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Table 4-5-7
CONSTITUENTS IN SITE 2E GROUNDWATER AND SOILS THAT EXCEEDED POTENTIALLY APPLICABLE FEDERAL AND VIRGINIA STANDARDS
February 1993
(All data in ppb)

Compound	Location Detected	Concentration (ppb)	Health Based Criteria for Carcinogens	Health Based Criteria for Systemic Toxicants	Proposed RCRA Action Levels	Virginia Soil Guidance Limit	Eastern United States Soil Mean
Copper	2E-SS5 (0.5) 2E-SS7 2E-SS8	31,200 41,000 58,000	NS	NS	NS	NS	13,000
Lead	2E-SS5 (2) 2E-SS7 2E-SS8	25,200 53,900 26,200	NS	NS	NS	NS	14,000
Mercury	2E-SS9	110	NS	NS	20,000	NS	81
Nickel	2E-SS9	11,500	NS	2,000,000	NS	NS	11,000
Zinc	2E-SS7 2E-SS8	105,000 74,000	NS	NS	NS	NS	40,000

Notes:
The MCLs and MCLGs are listed in the Drinking Water Regulations and Health Advisories, dated December 1992.
Only those compounds which were detected and exceeded established standards are presented in the table above.
The health-based criteria for carcinogens and systemic toxicants were extracted from the RFI Guidance Document EPA 530/SW-89-031
The proposed RCRA action limits were listed in the *Federal Register* dated July 27, 1990.
The Virginia soil guidance limit is used for determining when to implement a corrective action.
a These two concentrations are from the 0.5 - 1.0 foot and 2.0 - 3.0 feet depths, respectively.

Contaminants detected in the soils that exceeded standards were beryllium, arsenic, and benzo(a)pyrene. Benzo(a)pyrene exceeded the health-based criterion for carcinogens of 60.9 ppb in 2E-SS7 (98 ppb). The health-based criteria for beryllium is 143 ppb, which was exceeded in all 2E soil samples analyzed for inorganics. The concentrations of arsenic in all soil samples exceeded the risk-based concentrations for carcinogenic risk, calculated by Region III toxicologists (Smith, 1993). Arsenic concentrations were below calculated screening levels for non-carcinogenic risk. The average background concentration in the eastern United States (4.8 ppm) was also above the carcinogenic RBCs, so these levels may be naturally carcinogenic. Beryllium concentrations also typically exceeded the proposed RCRA action level but with one exception were not higher than the mean background concentration in the eastern United States. As stated in the section on Site 1, beryllium concentrations appear to be elevated at several of the RFI sites. Because beryllium is not known to be a waste product generated by station activities, the cause of the beryllium is unknown. Beryllium may be present at elevated background concentrations in soils over much of the station. Data in the soils literature support this conclusion. The mean background concentration of beryllium in soil in the eastern United States is 550 ppb (Shacklette and Boerngen, 1984). Only 2E-SS9 (0.57 ppm) is above this mean concentration.

Five metals were detected at concentrations below health-based criteria but above mean background concentrations for the eastern United States. Copper (4,200 to 58,000 ppb versus a background mean of 13,000 ppb), lead (4,200 to 53,900 versus 14,000 ppb), mercury (40 to 110 versus 81 ppb), nickel (5,400 to 11,500 versus 11,000 ppb), and zinc (8,700 to 105,000 versus 40,000 ppb) were all detected above this background in one or more samples.

The elevated TPH concentrations in 2E-SS5 (607,000 ppb), 2E-SS6 (189,000 ppb), and 2E-SS8 (286,000 ppb) exceeded the guidance limit of 100,000 ppb established by the Virginia Water Control Board.

The only contaminants detected in groundwater at Site 2E that exceeded applicable federal or state standards were mercury and zinc. Mercury and zinc concentrations did not exceed federal standards, but were above established Virginia groundwater standards of 0.05 ppb and 50 ppb, respectively. Both total and dissolved mercury and zinc were slightly above the Virginia standard in 2E-MW2 and total and dissolved mercury were slightly above the Virginia standard in 2E-MW3. Cadmium and thallium were not detected in any groundwater samples at instrument detection limits of 2.8 and 2.3 ppb, respectively. Manganese exceeded the aesthetic-based secondary MCLG in all wells, so the water would not be suitable for washing laundry because it would lead to discoloration.

Fate and Transport

The presence of free product in 2E-MW1 is the most significant environmental concern at this site. The free product in 2E-MW1 has appeared since the last field investigation in 1990. The source of this free product is unknown. No manholes are near 2E-MW1 and the manhole found to contain residual waste oil is near the south corner of Building 23, not near 2E-MW1. The free product smells and looks like diesel fuel, not waste oil, and the manhole is not directly upgradient of 2E-MW1, so the manhole dumping practices may not be the origin of the free product. Because the well lock or 2E-MW1 was rusted shut, it is unlikely that the well was vandalized.

Water-level elevations recorded from previous investigations indicate that localized groundwater flow is towards the southwest. For this reason, the source of the free product is most likely northeast or north of 2E-MW1. No known sources of free product are near or upgradient of the well. It is reasonable to assume that a contaminant plume is spreading to the southwest, but the rate of contaminant transport remains unknown because *in situ* hydraulic conductivity tests have not been performed. The groundwater system is serving as the principal transport mechanism for the spread of contamination.

The contaminants detected in the soils at Site 2E were present from the 0.5 to 1.0 foot and 2.0 to 3.0 feet depths. Possible transport mechanisms include soil erosion and downward leaching through the shallow soils to the water table.

Recommendations

The free product floating on the water table is being addressed. The NAS Oceana Department of Public Works has instituted a monthly program of free product recovery from Well 2E-MW1 by using a bailer. This site also is registered with the Virginia Department of Environmental Quality's Water Division under case number 94-0423. The RFI should be continued at this site in the area near and downgradient of 2E-MW1 by using a program of soil and *in situ* groundwater sampling followed by the installation and sampling of additional monitoring wells. The source of the free product also should be identified and investigated.

Site 11—Fire-Fighting Training Area

Site Location and History

Site 11 consists of two fire-fighting training rings and their immediate surroundings. The site is on the west side of NAS Oceana at the intersection of two abandoned runways. From the early 1960s until the mid-1970s, two fire-fighting practice sessions were conducted each weekend as part of training exercises (RGH, 1984). Fifty to seventy-five gallons of waste oil, fuel, chlorinated and aromatic hydrocarbons, and hydraulic fluid were poured into the center of the abandoned runway, ignited, and extinguished. In the mid-1970s, a fire pit with an earthen outer berm was built (RGH, 1984). Because of the added containment potential of the earthen berm, the volume of liquid wastes and fuels burned increased to approximately 50,000 gallons annually (RGH, 1984). Discussions with officials from the Public Works Department indicate that fuel and water would overflow the earthen berm occasionally (R. E. Wright, 1983).

Sources of ignition for the training fire, in addition to the waste listed above, included paint, paint thinners and strippers, naphtha, trichlorotrifluoroethane, and PD 680 (RGH, 1984). Recently, a new fire pit was constructed adjacent to the old one, where jet fuel is burned for fire-fighting training. The new ring has an oil-water separator system (RGH, 1984).

The IAS, also reported that the area directly west of the fire training pits on the west side of the abandoned runway was used for the disposal of waste fuels and lubricants by land farming (R. E. Wright, 1983). Land farming entails spreading hydrocarbon products over a large area, followed by tilling the soil to enhance volatilization and biodegradation (R. E. Wright, 1983). Personnel from the Environmental Division at Oceana could not confirm that the land farming occurred. The types of soils and the amount of fuel in the soils could not be determined, so the potential impact of this practice and its location could not be confirmed.

Past Investigations and RFI Site Activities

Site 11 was investigated as part of the Interim RFI. During the Interim RFI, one monitoring well was installed and sampled and four soil samples were collected. Results from the Interim RFI investigation indicate that constituents detected in groundwater were either near the detection limit (e.g., TPH) or could be attributed to minor laboratory contamination (e.g., methylene chloride).

The purpose of the RFI activities was to obtain a second round of groundwater data from a more extensive well network and to determine the extent of soil contamination at this site.

The RFI field investigation at Site 11 consisted of:

- The installation of two shallow monitoring wells (11-MW2 and 11-MW3)
- The sampling of groundwater from four wells (1-MW1, 11-MW1 through 11-MW3)
- The collection of six soil samples (11-SS5 through 11-SS10)

Four samples (11-SS5 through 11-SS8) were collected next to the old fire-fighting ring near the sampling location where TPH was detected during the Interim RFI. Two additional samples (11-SS9 and 11-SS10) were collected outside the newer fire-fighting ring. The six sampling locations were sampled from 0.5 to 1.0 foot and 2.0 to 3.0 feet. The samples were screened in the field with an organic vapor monitor (OVM) and the five most contaminated samples were sent to the CH2M HILL analytical lab in Montgomery, Alabama. A sample from location 11-SS8 was not submitted because the other locations produced higher OVM readings. The deeper sample typically produced higher readings, except at 11-SS10, where the shallow sample was submitted to the lab for analysis. The Site 11 monitoring wells were installed as indicated in Table 4-6-1. The RFI sampling locations are shown in Figure 4-6-1. Groundwater was analyzed for VOCs, PAHs, and total and dissolved metals in all wells except 11-MW2 where base-neutral extractable organics were substituted for PAHs. Soils were analyzed for TPH, VOCs, PAHs, and total metals.

Table 4-6-1
SITE 11 MONITORING WELL SUMMARY

Well Number	Date Installed	Ground Elevation (feet above MSL)	Total Depth (feet)	Screened Interval (feet below ground surface)
11-MW1	06/28/90	17.1	18	8-18
11-MW2	12/02/92	16.6	20.5	5.5-20.5
11-MW3	12/02/92	17.33	20	5-20

Environmental Setting

Ecology

Site 11 consists of concrete areas surrounded by tall grasses on the east and shrub forest and wetland areas to the west. Because Sites 1 and 11 are contiguous and their

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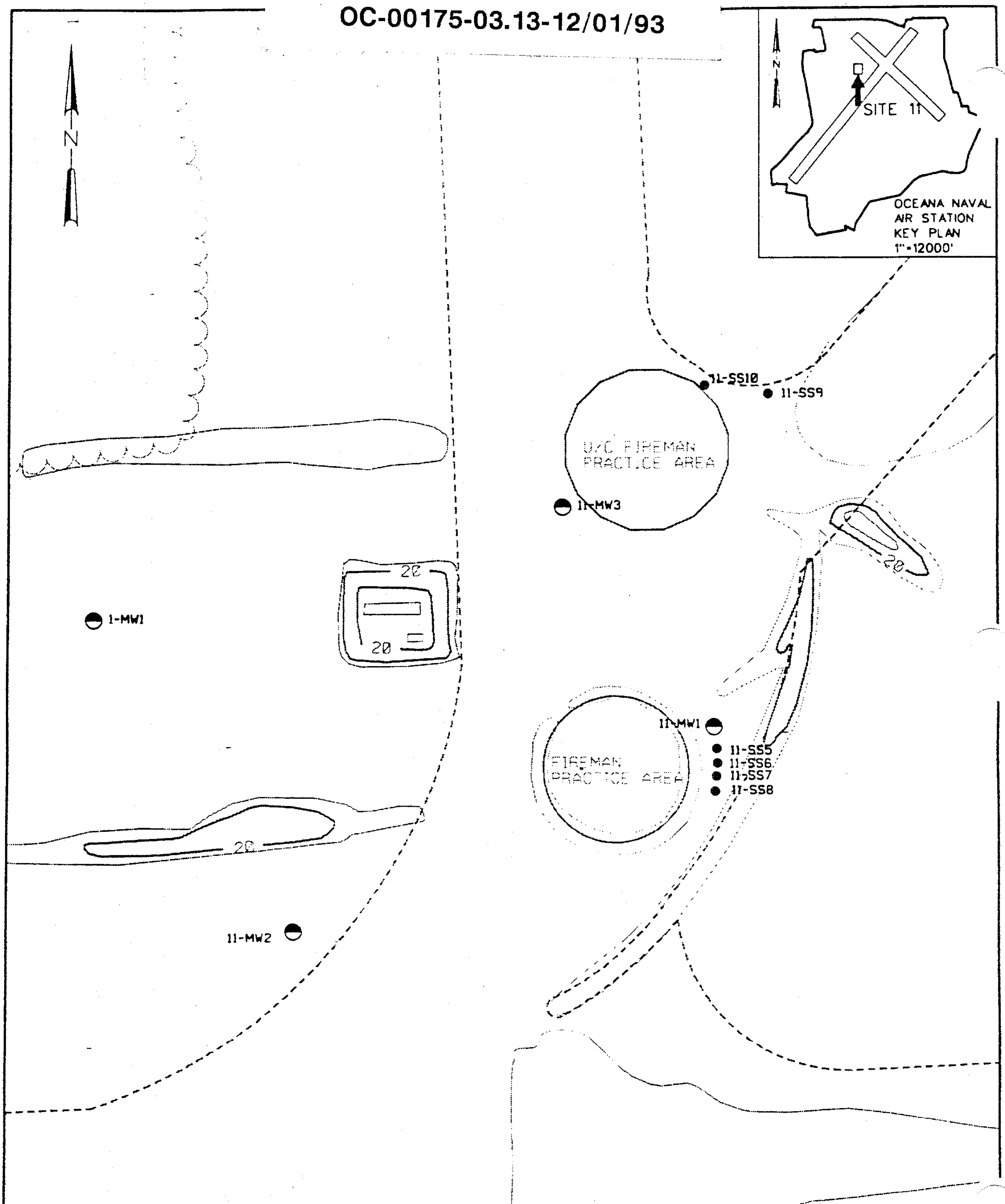

LEGEND

● SOIL SAMPLING LOCATIONS

◓ SHALLOW MONITORING WELL

0 50 100 1500

SCALE IN FEET

Figure 4-6-1

RFI SAMPLING LOCATIONS AT SITE 11 JANUARY - FEBRUARY 1993

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NOTE THAT NO SAMPLE WAS SUBMITTED FOR 11-SS8 environmental setting is linked, they are discussed as a coordinated whole in the Site 1 section of this chapter. Figure 4-1-2 is an ecological map of Sites 1 and 11. Refer to the Site 1 section for additional details.

Geologic and Hydrogeologic Characteristics

Shallow boreholes drilled as part of the Interim RFI and RFI provide information on the shallow geology at this site. The near-surface geology consists of a 5- to 10-foot thick layer of sandy clays with silty sands and clays. This layer is underlain by a 10- to 12-foot thick layer of clean sand with coarse grains. Both units are part of the Columbia Group sediments described in Chapter 2.

Water-level measurements collected in January 1993 are presented in Table 4-6-2. Figure 4-6-2 illustrates the equipotential contour lines in the clean Columbia Group sand. The data show that groundwater flow is west to southwest.

Table 4-6-2
SITE 11 WATER-LEVEL DATA
January 1993

Well	Depth to Water (Feet Below Survey Datum)	Water-Level Elevations (Feet Above Mean Sea Level)
11-MW1	6.09	13.16
11-MW2	6.85	12.97
11-MW3	4.09	13.24
1-MW1	4.29	12.84
1-MW2	6.00	12.59

Contamination and Extent

Groundwater

Groundwater samples collected from 11-MW1, 11-MW2, 11-MW3, and 1-MW1 during the RFI contained no volatile or semivolatile organic compounds above the quantitative detection limits. The results of the organic analyses are presented in Table 4-6-3.

All of the trace metal inorganics detected in groundwater samples were at or near the detection limit. Inorganic data are listed in Table 4-6-4. The sample collected from 1-MW1 contained low concentrations of arsenic in the total metals (14.6 ppb) and dissolved metals (14.2 ppb) samples.

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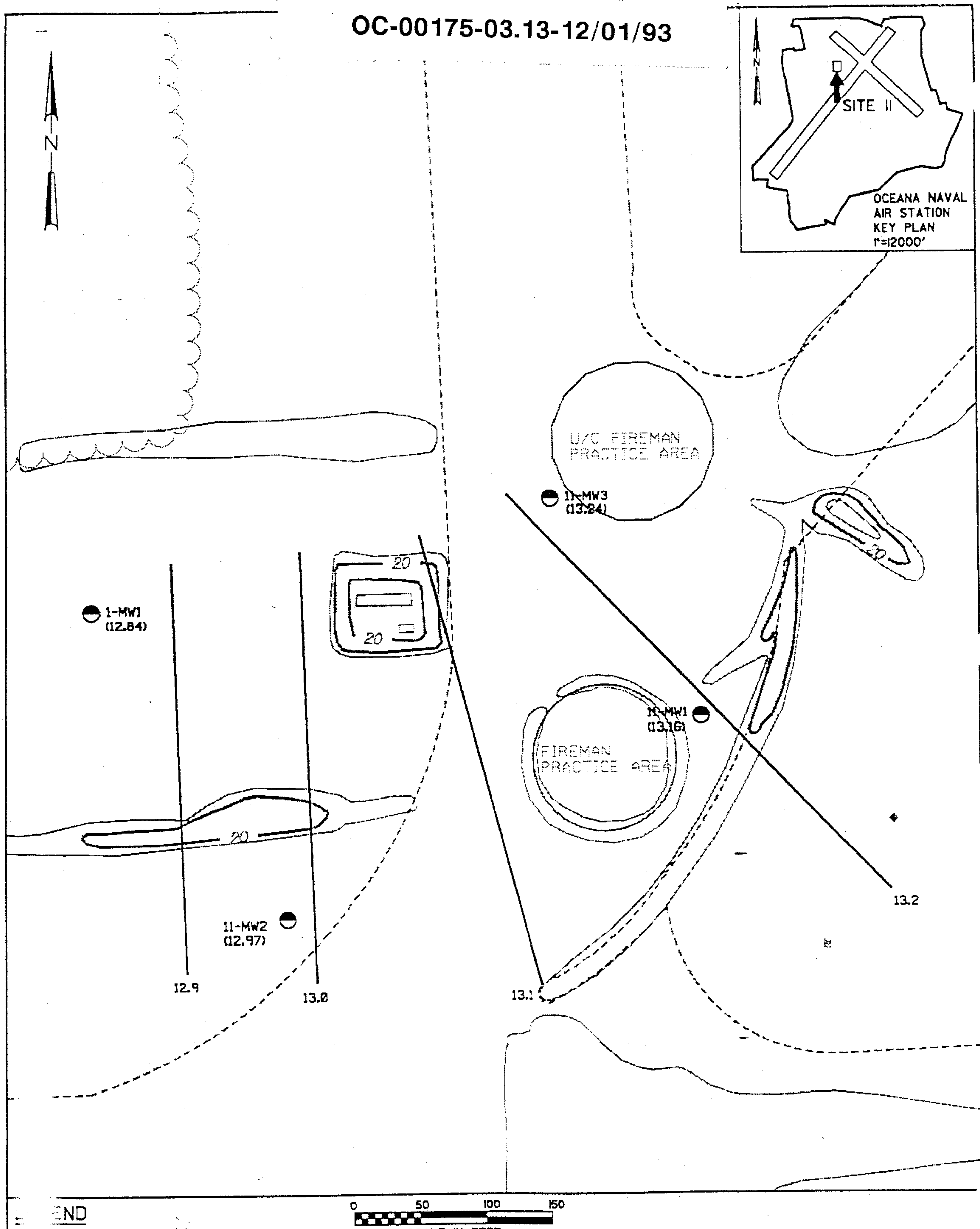

LEGEND

SOIL SAMPLING LOCATIONS

SHALLOW MONITORING WELL

Figure 4-6-2

WATER TABLE ELEVATIONS AND EQUIPOTENTIAL CONTOURS AT SITE II

JANUARY 25, 1993

CH2M HILL

Table 4-6-3
ORGANIC COMPOUNDS IN GROUNDWATER AT SITE 11
RESULTS OF RFI AND PREVIOUS STUDIES
(All data in μg/l)

Analyte	Detection Limit	1-MW1			11-MW1		11-MW2		11-MW3
		May 86	Aug. 90	Jan. 93	Aug. 90	Jan. 93	Jan. 93		Jan. 93
							Initial	Duplicate	
Volatile Organic Compounds									
Methylene Chloride	5	*	3 b,j	3 b,j	4 b,j	2 b,j	5 b	2 b,j	2 b
Acetone	10	*	6 b,j	6 j	5 b,j	4 j	8 j	6 j	5 j
Base Neutral Extractable Organics (Semivolatiles)									
Bis(2-Ethylhexyl)Phthalate	10	NA	NA	NA	20 b	NA	10 b	NA	N
Polynuclear Aromatics	2	NA	NA	*	NA	*	NA	NA	*
EDB	0.02	*	*	NA	NA	NA	NA	NA	N
PCBs	0.2	*	*	NA	NA	NA	NA	NA	N
TCDD	0.0002	<0.0002	<0.0006	NA	NA	NA	NA	NA	N
Oil and Grease	3,000	6,000	NA	NA	NA	NA	NA	NA	N
TPH	60	NA	NA	NA	120	NA	NA	NA	N

Notes:
All volatile, semivolatile, and polynuclear aromatic compounds not reported were below detection limits in all samples.
EDB - Ethylene Dibromide
TCDD - 2,3,7,8-dioxin
TPH - Total Petroleum Hydrocarbons
NA - Not analyzed
b - Compound found in laboratory blank as well as sample; sample concentration is less than 10 times blank concentration.
j - Estimated value. Measured value is less than the accurately quantitative detection limit.
*Concentration below detection limit.
< - The value was less than the detection limit, or was not detected.

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Table 4-6-4
INORGANIC COMPOUNDS IN GROUNDWATER AT SITE 11
January 1993
(Concentrations in $\mu g/l$)

Analyte	1-MW1		11-MW1		11-MW2				11-MW3	
					Initial		Duplicate			
	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved
Silver	<2.0	<2.0	2.1 b	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Aluminum	613	45.2 b	436	62.7 b	341	45.2 b	324	57.4 b	922	74.4 b
Arsenic	14.6	14.2	4.7 b	2.3 b	4.4 b	4.6 b	4.9 b	4.1 b	2.7 b	1.2 b
Barium	19.5 b	17.6 b	13.4 b	9.6 b	19.6 b	17.0 b	20.4 b	17.4 b	19.3 b	12.2 b
Beryllium	0.37 b	<0.26	0.43 b	<0.26	<0.26	<0.26	<0.26	<0.26	<0.26	<0.26
Calcium	5,970	6,190	2,970 b	3,560	9,540	9,120	9,800	9,280	14,300	12,800
Cadmium	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8
Cobalt	<2.6	<2.6	3.9 b	<2.6	<2.6	<2.6	<2.6	<2.6	<2.6	<2.6
Chromium	3.9 b	3.6 b	5.4 b	<2.8	3.3 b	<2.8	3.8	<2.8	5.5 b	3.0 b
Copper	1.4 b	<1.2	3.4 b	<1.2	1.7 b	<1.2	<1.2	<1.2	2.5 b	<1.2
Iron	10,000	8,670	6,450	3,940	10,900	9,900	11,600	10,000	7,200*	5,190
Mercury	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	0.11 b	<0.07	<0.07	<0.07
Potassium	1,950 b	1,370 b	2,380 b	1,700 b	<934	<934	1,390 b	<934	1,660	1,240
Magnesium	11,200	11,400	4,780 b	4,590 b	12,300	11,900	13,100	12,100	7,720	7,210
Manganese	395	419	55.3 b	53.8	319	305	349	307	239	214
Sodium	15,600	14,700	17,800	16,900	14,200	13,400	14,500	13,600	12,300	11,500

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Table 4-6-4
INORGANIC COMPOUNDS IN GROUNDWATER AT SITE 11
January 1993
(Concentrations in $\mu g/l$)

Analyte	1-MW1		11-MW1			11-MW2				11-MW3	
			August 1990	January 1993		Initial		Duplicate			
	Total	Dissolved		Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved
Nickel	<9.4	<9.4	NA	9.7 b	<9.4	<9.4	<9.4	9.9 b	<9.4	<9.4	<9.4
Lead	<1.7	<1.7	<3	2.1 b	<1.7	2.9 b	1.8 b	2.1 b	<1.7	<1.7	<1.7
Antimony	<16.4	<16.4	NA	<16.4	<16.4	<16.4	<16.4	<16.4	<16.4	<16.4	<16.4
Selenium	<1.8	<1.8	NA	<1.8	<1.8	<1.8	<1.8	<1.8	1.8	<1.8	<1.8
Thallium	<2.3	<2.3	NA	<2.3	<2.3	<2.3	<2.3	<2.3	<2.3	<2.3	<2.3
Vanadium	<2.6	<2.6	NA	3.7 b	<2.6	<2.6	<2.6	<2.6	<2.6	<2.6	<2.6
Zinc	35.5	41.0	NA	24.7	19.1 b	21.5	15.4 b	24.5	19.2	32.8	14.8 b
Tin	NA	NA	NA	NA	NA	NA	NA	NA	<12.7	NA	NA

Notes:

QC Sampling - 11-MW30 is a duplicate of 11-MW2
NA - Not analyzed
b - The reported value was less than the CRDL, but greater than or equal to the IDL
<The value constituent was not detected at this IDL.
[a]Poor duplicate precision

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Soils

Analytical results for organics and inorganics in soils are presented in Tables 4-6-5 and 4-6-6. The VOCs detected were either near or below the contract-required detection limit (CRDL) or were common laboratory contaminants detected in the associated laboratory blanks at comparable concentrations. None of the organic compounds was detected consistently in all soil samples.

Polynuclear aromatic compounds were not detected in any Site 11 soil samples. Total petroleum hydrocarbons were present in all samples except 11-SS9. TPH concentrations were low in 11-SS5 (9,200 ppb), 11-SS6 (2,500 ppb), and 11-SS7 (5,100 ppb). The TPH concentration was high compared to Virginia guidelines in 11-SS10 (325,000 ppb)

Several metals were detected in soils, however, most were present at concentrations below or near the detection limit or are abundant in natural soils.

Health and Environmental Assessment

Table 4-6-7 presents the compounds that were found in soil and groundwater that exceeded applicable federal or Virginia standards or guidelines or were above mean background soil concentrations for the eastern United States. The only compounds detected in the soil that exceeded potential standards or guidelines were beryllium and TPH. All five Site 11 soil samples contained beryllium concentrations above the health-based criterion for carcinogens of 143 ppb and the proposed RCRA action level of 200 ppb. Because of high beryllium concentrations at several sites throughout the station, it is uncertain whether these beryllium levels are the result of site activities. The mean background concentration of beryllium in the eastern United States is 550 ppb (Shacklette and Boerngen, 1984). Only one sample, 11-SS6 at 630 ppb, was slightly above this mean. The TPH standard of 100,000 ppb is a guidance limit used by the Virginia Water Control Board to determine if a corrective action should be implemented (Jacobeen, 1993). The TPH concentration of 325,000 ppb detected in 11-SS10 exceeds the Virginia guidance limit.

Mercury and manganese were detected in groundwater at concentrations above established standards or goals. Mercury's presence in the environment is uncertain because it was not detected in the associated duplicate sample. The mercury concentration of 0.11 ppb detected in 11-MW2 exceeds the Virginia groundwater standard of 0.05 ppb. This concentration does not exceed either the MCL (2 ppb) or the MCLG (2 ppb). Manganese was detected in concentrations ranging from 214 ppb to 419 ppb. This range of concentrations exceeds the secondary MCLG of 200 ppb established for aesthetic reasons related to discoloration of household laundry.

Table 4-6-5
ORGANIC COMPOUNDS IN SOIL AT SITE 11
February 1993
(All data in µg/kg)

Analyte	August 1990					February 1993				
	11-SS1									
	Initial	Duplicate	11-SS2	11-SS3	11-SS4	11-SS5	11-SS6	11-SS7	11-SS9	11-SS10
TPH	9,300	6,300	22,900	18,800	289,000	9,200	2,500	5,100	<2,000	325,000
Volatile Compounds										
Methylene Chloride	57 b	45 b	76 b	65 b	27 b	13 b	24 b	18 b	25 b	15 b
Acetone	27 b	17 b	60 b	26 b	19 b	30	45	37	13	65
2-Butanone	*	*	*	*	*	13	19	*	*	*
Toluene	*	*	*	*	*	2 j	*	*	1 j	2 j
Ethylbenzene	*	*	*	*	*	2 j	*	*	*	*
Xylene (total)	*	*	*	*	*	6 j	2 j	*	3 j	2 j
Carbon Disulfide	*	*	*	*	*	*	1 j	*	*	*
Semivolatile Compounds										
Bis(2-ethylhexyl)Phthalate	640	310 j	110 j	98 j	54 j	NA	NA	NA	NA	NA
Polynuclear Aromatics	NA	NA	NA	NA	NA	*	*	*	*	*
Ignitability	NI	NI	NI	NI	NI	NA	NA	NA	NA	NA

Notes:
11-SS3 and 11-SS4 were sampled as part of the interim RFI. Their inclusion in this table results from their relative proximity to the samples which were collected as part of the RFI (11-SS5 through 11-SS10). The RFI samples were collected in the area between 11-SS3 and 11-SS4.
TPH - Total Petroleum Hydrocarbons
(*) - Compound analyzed, but not detected in any samples
b - The analyte is found in the associated blank as well as the sample
j - Indicates an estimated value
NI = Nonignitable

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Table 4-6-6
INORGANIC COMPOUNDS IN SOILS AT SITE 11
August 1990 and February 1993
(All data in mg/kg)

Analyte	August 1990					February 1993				
	11-SS1		11-SS2	11-SS3	11-SS4	11-SS5	11-SS6	11-SS7	11-SS9	11-SS10
	Initial	Duplicate								
Aluminum	NA	NA	NA	NA	NA	20,400	16,300	19,400	18,900	11,400
Antimony	NA	NA	NA	NA	NA	<3.9	<4.2	<4.1	<3.9	<3.6
Arsenic	NA	NA	NA	NA	NA	2.2 B	1.7 B	1.5 B	1.9 B	2.0 B
Barium	NA	NA	NA	NA	NA	88.4	85.1	61.0	76.2	37.8 B
Beryllium	NA	NA	NA	NA	NA	0.54 B	0.63 B	0.55 B	0.55 B	0.29 B
Cadmium	NA	NA	NA	NA	NA	<0.66	<0.70	<0.69	<0.65	<0.61
Calcium	NA	NA	NA	NA	NA	606 B	776 B	1,230 B	1,280	1,030 B
Chromium	NA	NA	NA	NA	NA	19.9	16.4	32.7	20.3	15.0
Cobalt	NA	NA	NA	NA	NA	3.0 B	3.2 B	3.9 B	3.4 B	2.5 B
Copper	NA	NA	NA	NA	NA	7.1	6.8	10.8	6.0	4.3 B
Iron	NA	NA	NA	NA	NA	5,470	4,390	12,500	6,480	7,360
Lead	9	9.6	11.4	10.9	10.4	12.2	12.4	9.6	12.8	9.4
Magnesium	NA	NA	NA	NA	NA	885 B	797 B	1,050 B	1,010 B	827 B
Manganese	NA	NA	NA	NA	NA	18.4	17.3	22.3	25.6	23.5

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Table 4-6-6
INORGANIC COMPOUNDS IN SOILS AT SITE 11
August 1990 and February 1993
(All data in mg/kg)

Analyte	August 1990					February 1993				
	11-SS1		11-SS2	11-SS3	11-SS4	11-SS5	11-SS6	11-SS7	11-SS9	11-SS10
	Initial	Duplicate								
Mercury	NA	NA	NA	NA	NA	<0.04	<0.04	<0.04	<0.04	<0.03
Nickel	NA	NA	NA	NA	NA	8.5 B	7.0 B	9.3 B	8.4 B	4.7 B
Potassium	NA	NA	NA	NA	NA	429 B	392 B	712 B	326 B	353 B
Selenium	NA	NA	NA	NA	NA	0.97 B	0.86 B	0.64 B	0.71 B	0.47 B
Silver	NA	NA	NA	NA	NA	<0.48	<0.50	<0.50	<0.47	<0.44
Sodium	NA	NA	NA	NA	NA	374 B	206 B	214 B	212 B	212 B
Thallium	NA	NA	NA	NA	NA	<0.55	0.62 B	<0.58	<0.55	0.55 B
Vanadium	NA	NA	NA	NA	NA	22.3	18.6	32.5	22.6	16.9
Zinc	NA	NA	NA	NA	NA	13.9	17.2	22.4	19.4	16.1

Notes:
< The constituent was not detected at this instrument detection limit (IDL).
B The reported value was less than the Contract Required Detection Limit, but greater than or equal to the IDL.

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Table 4-6-7
ORGANIC AND INORGANIC CONSTITUENTS DETECTED IN THE SITE 11 SOIL AND GROUNDWATER THAT EXCEEDED POTENTIALLY APPLICABLE FEDERAL AND STATE STANDARDS AND BACKGROUND LEVELS
February 1993
(All data in ppb)

Compound	Location Detected	Concentration (ppb)	Health-Based Criteria for Carcinogens	Health-Based Criteria for Systemic Toxicants	Proposed RCRA Action Level	Virginia Soil Guidance Limit	Background Soil Concentration Eastern United States
Soil							
Total petroleum hydrocarbons	11-SS10	325,000	--	--	--	100,000 ppb	ND
Beryllium	11-SS5 11-SS6 11-SS7 11-SS9 11-SS10	540 630 550 550 290	143	400,000	200	NS	550
Selenium	11-SS5 11-SS6 11-SS7 11-SS9 11-SS10	970 860 640 710 470	NS	NS	NS	NS	300

Compound	Location Detected	Concentration (ppb)	MCL	MCLG	Proposed RCRA Action Level	Virginia Groundwater Standard	Background Soil Concentration Eastern United States
Groundwater							
Mercury	11-MW2	0.11	2	2	2	0.05	NA

Notes:
Only compounds that were detected and exceeded applicable standards are presented in this table.
The health-based criteria for carcinogens and systemic toxicants were listed in the RFI guidance document, EPA 530/SW-89-031.
The proposed RCRA action levels were included in the Federal Register dated July 27, 1990.
The MCL and MCLG figures were extracted from the Drinking Water Regulations and Health Advisories, December 1992.
a - Maximum concentration from all soil samples at Site 11.
ND - No data.
NS - No standard.
NA - Not applicable.

The concentrations of two other inorganic elements, thallium and antimony, merit additional discussion. The IDL for antimony is 16.4 ppb, and the IDL for thallium is 2.3 ppb. Neither metal was detected above its respective IDL; however, the MCLs for these inorganics are 6 ppb and 2 ppb, respectively. By using the concentrations derived from the laboratory analyses, determining if the metals are in the groundwater at levels exceeding the MCL is not possible. In addition, the concentration of arsenic in 11-MW1 (14.6 ppb) is above the risk-based concentration of 11 ppb calculated by toxicologists at the Region III office of the EPA (Smith, 1993).

The concentrations of selenium in all the soil samples analyzed for metals were higher than the mean background concentrations in the eastern United States but were below health-based or ecological criteria. Selenium concentrations ranged from 470 to 970 ppb versus a mean background concentration of 300 ppb (Shacklette and Boerngen, 1984). Selenium concentrations were less than the contract-required detection limit in all cases, however, so it is unlikely that the selenium is present because of fire-fighting activities.

Fate and Transport

The Site 11 soil samples were collected from a depth of 2.0 to 3.0 feet, therefore, the known contamination is present at a depth where it is not subject to soil erosion. Shallow soils are believed to be less contaminated with VOCs based on OVM screening but may be higher with respect to TPH based on soil staining. Precipitation leaching through the shallow soils to the water table may transport the contaminants to the groundwater; however, soil concentrations are not high and analytical results for groundwater do not indicate groundwater contamination.

Recommendations

Although analytical data do not support additional work at the site, because soils were visibly contaminated by petroleum, limited testing for TPH may be appropriate at shallower depths. Therefore, the RFI should be continued, first by defining surficial TPH contamination in soils and then by implementing an appropriate removal action.

Site 15—Abandoned Tank Farm

Site Location and History

This site is in the former North Station area, approximately 800 feet northwest of Runway 23R and 1,000 feet northeast of the area used to store recreation vehicles near the old CPO officers' club (Figure 4-7-1). The abandoned tank farm served as the primary source of aircraft fuel for the North Station area when it was active from the mid-1950s to the mid-1970s. As shown in Figure 4-7-1, the tank farm consisted of six tanks: a 414,000-gallon tank used to store JP-3, two 50,000-gallon concrete tanks used for aviation gas, and three adjacent 12,000- to 18,000-gallon tanks believed to be used for automotive fuel, kerosene, or lube oil (RGH, 1984; Navy, 1957).

According to a report by R. E. Wright Associates, the tanks were emptied of fuel and filled with water after they were abandoned (R. E. Wright Associates, 1983). Tank G-5 was later used to store waste oil. The tanks and their associated piping were dismantled and removed in the mid-1980s. With the exception of some mounded earth near the former location of tank G-9, no signs of the locations of the tanks or their associated piping were observed during the RFI. Their locations were inferred from historical maps of the North Station area (Navy, 1957).

Past Investigations and RFI Site Activities

The earliest environmental investigation of this site was conducted by R. E. Wright Associates in 1982. Field activities included installing four wells (MW-1 through MW-4) and excavating three test pits (BP-8, BP-9, and BP-10). The locations of the wells and test pits are shown in Figure 4-7-1. Tank G-9 was not indicated on the figures in the 1983 R.E. Wright report, so the tank may have been removed before December 1982.

Some amount of free-product fuel was observed in all three test pits and in all well borings except MW-1; however, only well MW-3 contained free product after it was completed. R. E. Wright concluded that the free-product fuels observed were probably not highly mobile and that the dissolved contaminants associated with these fuels were insignificant.

Site 15 was identified as a potential hazard during the IAS in 1984. The two 50,000-gallon tanks were still present during this investigation and tank G-5 was still thought to contain approximately 5,000 gallons of waste liquids. The composition of the liquid was not known but may have contained paints, thinners, paint strippers, PD 680, engine cleaner, and naphtha in addition to waste fuels, oils, and hydraulic fluid (RGH, 1984). Because the previous study had concluded that the contamination was insignificant, no additional sampling was proposed.

During the RFA in 1988, reviewers concluded that this site was potentially hazardous and recommended further sampling and study (EPA, 1988). No tanks or piping were observed during the RFA.

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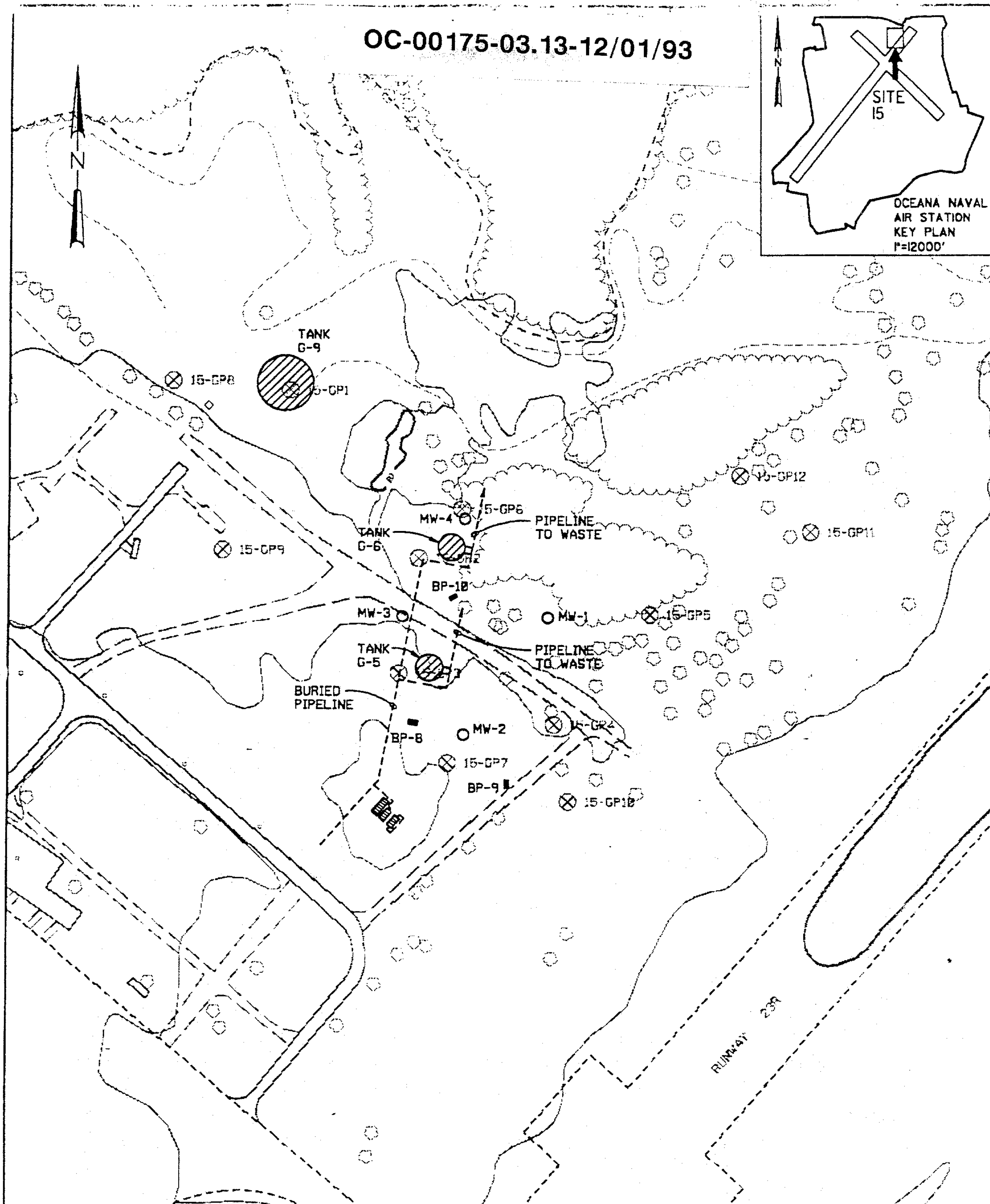

LEGEND

- ⊗ HYDRAULIC PROBE SAMPLING LOCATION
- O PREVIOUS MONITORING WELL
- ▫ BACKHOE PIT WITHOUT STANDPIPE
- --- FORMER BURIED PIPELINE

0 100 200 300
SCALE IN FEET

LOCATIONS ESTIMATED FROM DIAGRAMS IN R.E. WRIGHT, 1983 AND NAVY, 1957

Figure 4-7-1
ESTIMATED LOCATIONS OF ABANDONED TANKS, PIPING, AND PREVIOUS SAMPLING POINTS AT SITE 15

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The proposed approach for the RFI investigation at this site was to consult air photos to pinpoint the former locations of the tanks, then to further define their location and the extent of contamination by using *in situ* soil-gas and groundwater sampling. On the basis of these findings, the site would be investigated further in the second phase of the RFI.

Before *in situ* sampling began during the RFI, a map showing the locations of the former tanks in 1957 (Navy, 1957) was located in the Public Works archives. A review of the data from the R. E. Wright investigation showed that the depth to groundwater was only 1 to 3 feet. Because the shallowness of the water table might have led to poor soil-gas recovery, the EPA and the Navy agreed to abandon soil-gas sampling and collect more *in situ* groundwater samples. A total of 12 *in situ* groundwater samples (15-GP1 through 15-GP12) were collected at the locations shown in Figure 4-7-2. Each was analyzed for BTEX compounds, TPV, and several chlorinated solvents by using an onsite mobile lab. TPV is a summation of unidentified petroleum-related volatiles detected by the gas chromatograph (GC). A split of 15-GP6 was collected and analyzed for Method 8020 aromatic volatiles. 15-GP6 also was analyzed for total and dissolved lead and PAHs because it had a strong fuel odor. The ecology of the site also was studied as described in Appendix A.

Environmental Setting

The area around Site 15 includes pavement, forests, scrub/shrub areas, and some wetlands. The terrain is relatively flat. Drainage is generally toward the northeast. Figure 4-7-3 is an ecological map of Site 15. As shown in Figure 4-7-3, a shallow ditch is in the forested area, slightly north of the tank locations. A small depressional area was observed that may be a remnant ditch also. Much of the site is covered in dilapidated paved road surfaces and parking lots. Most of the other ground surface has previously disturbed soils, and open fields that may have been old dirt roads or locations of former tanks or buildings. An emergent wetland was identified near the runway. A part of the forested area along the ditch also was thought to be wetland. Other parts of the site were considered upland and were dominated by mostly primary-successional vegetation.

Ecology

Surface Water Resources. A series of ditches occurs immediately north of Site 15. One of the ditches was located during the field survey. The ditches on or near the site generally flow toward the northeast. The northwest-southeast ditch just north of the site contained water in most of the ditch, however, it did not appear to be flowing at the time of assessment. Water quality appeared to be good because there was a lack of precipitate and odor. The water was very dark, perhaps caused by the tannins in the leaf litter that covered most of the ditch bottom. A culvert was located that went under what is now used as a horseback riding trail.

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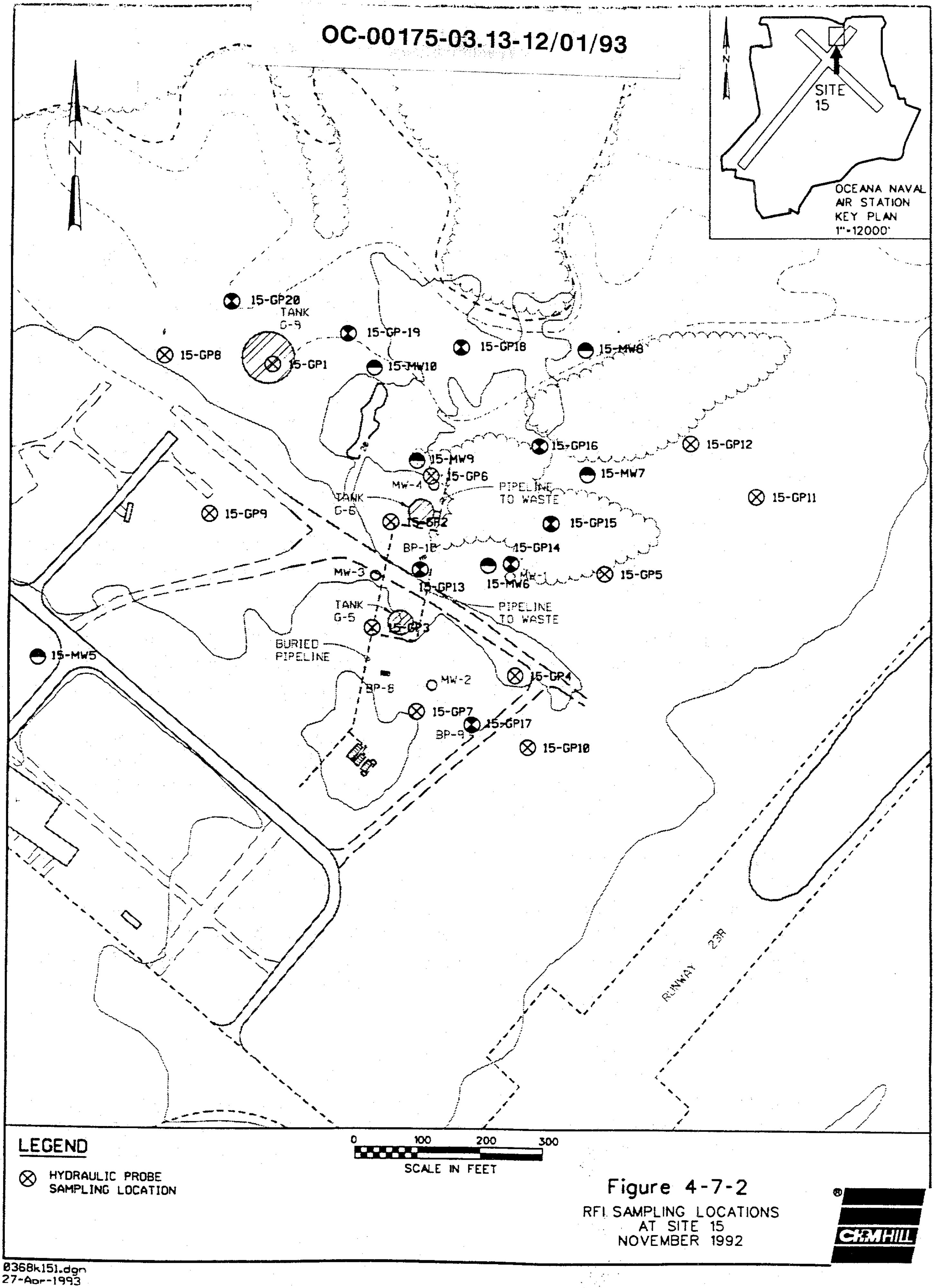

Figure 4-7-2
RFI SAMPLING LOCATIONS AT SITE 15 NOVEMBER 1992

Wetlands. A fairly large emergent wetland was observed near the runway. The wetland apparently has formed in a shallow depression that holds water because of compact silty clay soils and poor drainage. Water was ponded in the wetland at the time of the field survey. Because of standing water and compact soils, much of the wetland was unvegetated.

Vegetation. Because most of the area had been previously disturbed, much of the vegetative community is dominated by primary successional plant species, adapted to living in those conditions. Some of these plant species include: bluestem grass, panic grass, goldenrod species, giant cane, and groundsel tree. Dense stands of even-aged shrubs and sapling-size trees are along the parts of the old field areas and unpaved roadbeds. These stands were most often made up of wax myrtle, loblolly pine, multiflora rose, and blackberry. Thick stands of giant cane are throughout the area. The mature forests are dominated by sweetgum, red maple, tulip poplar, blackgum, wax myrtle, and Japanese honeysuckle. A large stand of mature loblolly pine occurs immediately north of the study area.

The vegetation in the small depressional wetland north of the tanks was dominated by red maple saplings, wool grass, and soft rush. The large emergent wetland is contiguous to the maintained part of the runway corridor. The vegetative community is dominated by soft rush, plume grass, wool grass, water purslane, and smartweed.

Visible signs of vegetative stress were limited and probably caused by natural conditions in the wetland. Some siltation deposits, algae, and orange-colored precipitation was observed in the wetland area. No signs of vegetative stress were observed in other parts of the site.

Wildlife. Birds were a common sight at this location. Among the species observed were rufous-sided towhee, tufted titmouse, catbirds, and yellow-rumped warblers. Also observed were a pair of common flickers in a den hole in an telephone pole. Other species observed at the site are listed in Appendix A.

Some mammal signs were observed in the area, but no animals were seen. Many white-tailed deer trails, tracks, and beds were found throughout the scrub-shrub and old field areas. Muskrat and raccoon tracks were identified in the wetland area. An unidentified species of crayfish, and a species of insect called water boatmen were found where sufficient ponding occurred. Cottontail rabbit, opossum, and woodchuck probably inhabit the dryer areas, because of the available habitat. Tracks found along the perimeter of the runway corridor were probably those of a grey fox.

Geologic and Hydrogeologic Characteristics

No information on site geology or hydrogeology was collected during the RFI; however, some data is available in the report by R. E. Wright. Test pits and soil borings described in the 1983 report indicate that the site is underlain by silts and sands in two general units.

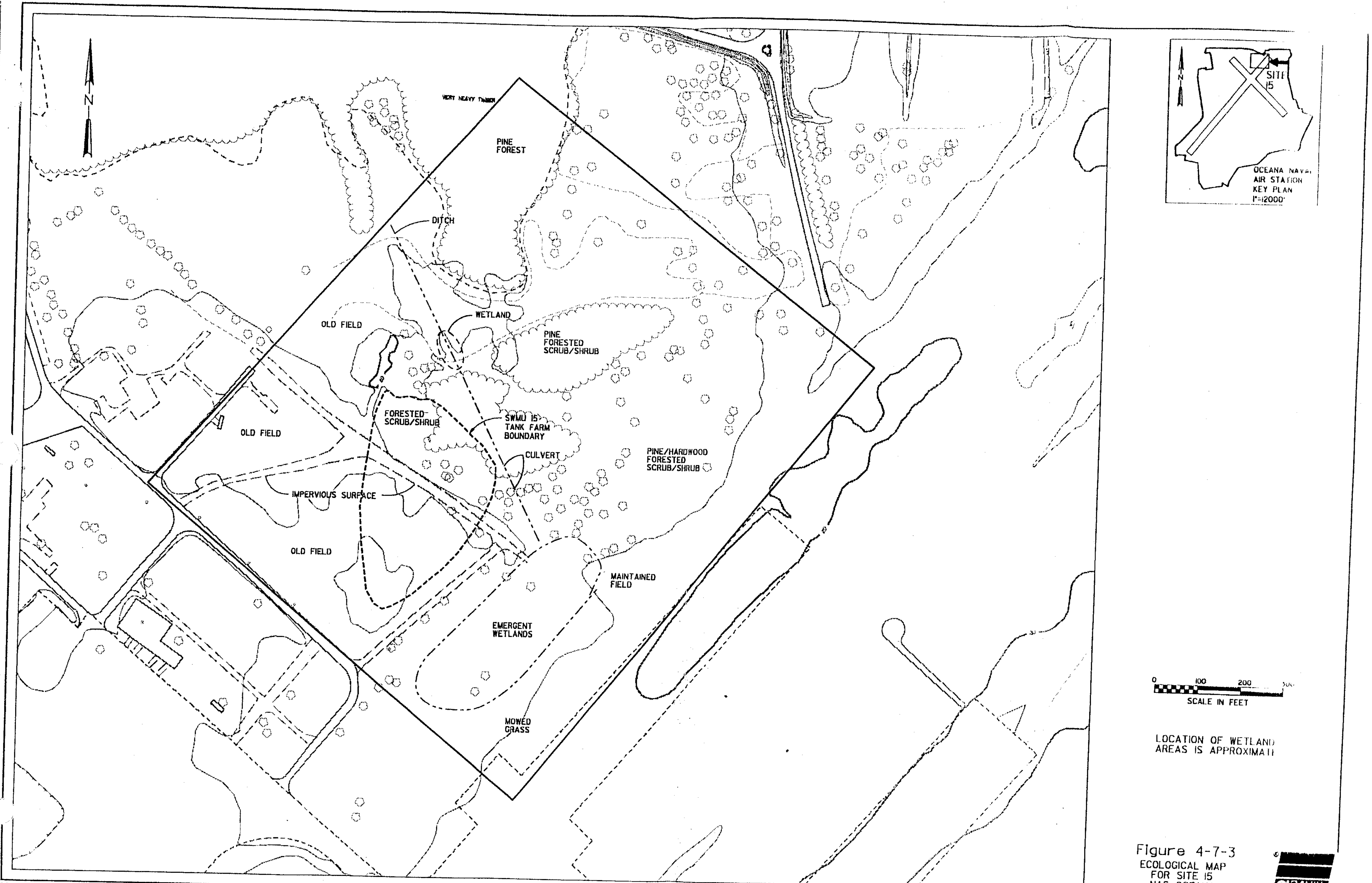

Figure 4-7-3
ECOLOGICAL MAP FOR SITE 15 NAS OCEANA

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The first unit consists of silt and slightly sandy silts from the surface to 5 to 7 feet. This is underlain by clean sands and silty sands to final borehole depths of 16 to 20 feet. These units are similar to the surficial units seen throughout most of the station. They correspond to the Columbia Group sediments described in Chapter 2.

The water levels measured in the four monitoring wells on December 7, 1982, indicated that groundwater flowed to the northeast (R. E. Wright, 1983). Horizontal groundwater gradients were quite low: approximately 0.0004 to 0.0007 vertical feet per linear foot. This suggests that the direction of groundwater flow may be variable, especially in response to localized mounding. The wells installed by R. E. Wright could not be located during the RFI. As a result, the water levels could not be measured to confirm the direction of groundwater flow.

Contamination and Extent

Aromatic volatiles were found in the groundwater at this site, which indicates that some fuel releases have occurred. Strong fuel odors were detected at most of the 12 sampling locations. Table 4-7-1 lists the concentrations of the chlorinated solvents, aromatic volatiles, TPV, lead, and PAHs detected in groundwater at Site 15.

Total petroleum volatiles were detected in all but 4 of the 12 samples, aromatic volatile compounds were detected in 15-GP2, 15-GP3, and 15-GP6 and trans-1,2-DCE was detected in 15-GP8. None of the analyzed contaminants was detected at 15-GP11 and 15-GP12; however, groundwater samples from both locations had a fuel odor.

Figure 4-7-4 shows the distribution of total petroleum volatiles and the sum of the concentrations of BTEX in groundwater at the site. This figure illustrates that contamination is highest in the center of the site near tanks G-5 and G-6. Concentrations were exceptionally high in 15-GP6, where the concentration of total petroleum volatiles was 1,600,000 ppb, or 0.16 percent by volume. Total BTEX concentrations were 57,900 ppb.

Groundwater contamination by fuels extends beyond the center of the site as shown by the TPV results. The TPV results provide a more generalized view of fuel-related contamination at this site because a broader spectrum of fuel-related compounds is detected. This is important at Site 15 because releases may have dated from the earliest use of the tank farm in the mid-1950s. Older fuel releases would be highly degraded and would be expected to lack BTEX compounds.

TPV concentrations generally decrease with distance away from the center but also show a possible fuel source in the south near 15-GP7. TPV was elevated in 15-GP7 (660 ppb), 15-GP5 (270 ppb), and 15-GP8 (100 ppb) and slightly elevated in 15 GP-4 (29 ppb) and 15-GP1 (11 ppb). A review of Figure 4-7-1 shows that the three small tanks were near or upgradient of 15-GP7, suggesting that releases from this area may have occurred. The results at 15-GP4 and 15-GP5 are consistent with the high concentrations found in 15-GP3 and may be related to a release from tank G-5.

Table 4-7-1
ORGANIC COMPOUNDS AND LEAD IN GROUNDWATER AT SWMU 15
RFI RESULTS
(All concentrations in µg/l)

Analyte[a]	Detection Limit	15-GP1	15-GP2	15-GP3	15-GP4	15-GP5	15-GP6		15-GP7	15-GP8	15GP-9	15-GP10	15-GP11	15-GP12
							Field Lab	Standard Lab[b]						
Aromatic Volatile Organic Compounds														
Benzene	10	*	6.3	86	*	*	16,000	620	*	*	*	*	*	*
Toluene	10	*	4.3	32	*	*	6,900	960	*	*	*	*	*	*
Ethylbenzene	10	*	3.7	*	*	*	13,000	2,600	*	*	*	*	*	*
o-Xylene	100	NA	NA	NA	NA	NA	NA	3,200	NA	NA	NA	NA	NA	NA
m-and p-xylene	200	NA	NA	NA	NA	NA	NA	10,000	MA	NA	NA	NA	NA	NA
Total xylenes	10	*	15	3,300	*	*	22,000	13,200	*	*	*	*	*	*
Chlorinated Volatile Organic Compounds														
trans-1,2-dichloroethylene	2	*	*	*	*	*	*	NA	*	11	*	*	*	*
Total Petroleum Volatiles	10	11	1,100	13,000	29	270	1,600,000	NA	660	100	*	*	*	*
Lead - total	1.7	NA	NA	NA	NA	NA	NA	668	NA	NA	NA	NA	NA	NA
- dissolved		NA	NA	NA	NA	NA	NA	25.8	NA	NA	NA	NA	NA	NA
Polynuclear Aromatic Hydrocarbons														
Naphthalene	2	NA	NA	NA	NA	NA	NA	26	NA	NA	NA	NA	NA	NA
2-Methylnaphthalene	2	NA	NA	NA	NA	NA	NA	18	NA	NA	NA	NA	NA	NA
1-Methylnaphthalene	2	NA	NA	NA	NA	NA	NA	12	NA	NA	NA	NA	NA	NA

Notes:

[a]Field analysis was for Mobile Lab chlorinated VOCs, total petroleum volatiles, and Mobile Lab aromatic VOCs; 15-GP6 was split and analyzed for 8020 aromatic volatiles, total and dissolved lead, and 8100.
[b]Positive VOC results were qualified as tentatively identified during validation process because the results were not confirmed by second column analyses.
NA - Not analyzed.
*Concentration below detection limit
Field GC detection limits were 10 ppb for aromatic VOCs and 2 ppb for chlorinated VOCs. Standard lab detection limits are listed above.

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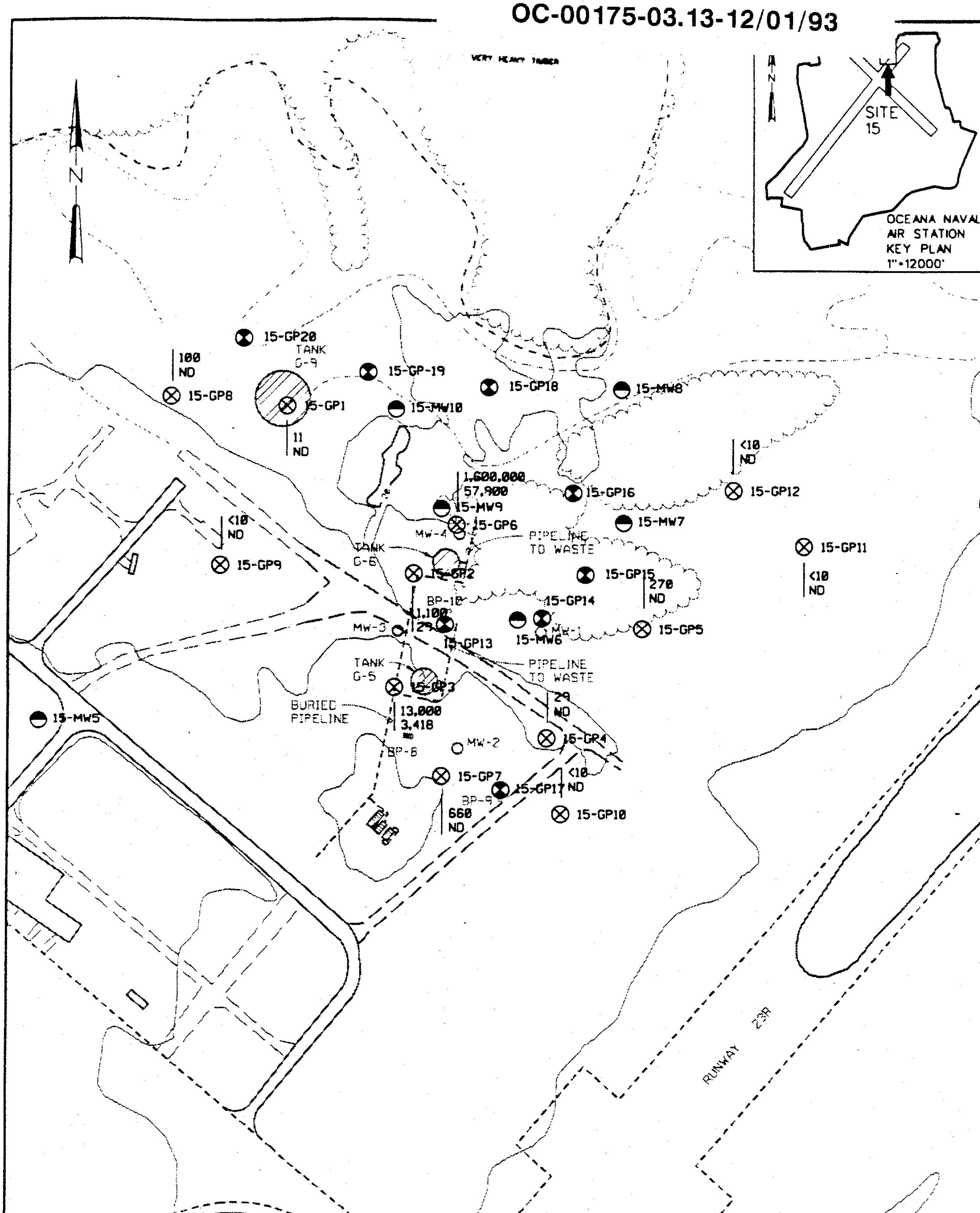

LEGEND

TPV
BTEX

⊗ HYDRAULIC PROBE SAMPLING LOCATION

RESULTS ARE IN PPB, FROM THE MOBILE LABORATORY

Figure 4-7-4

DISTRIBUTION OF TPV AND BTEX COMPOUNDS AT SITE 15
NOVEMBER 1992

CH2M HILL

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12-Nov-1993

The data near former tank G-9 do not appear to indicate substantial contamination. 15-GP1 results were very low considering that the sampling point was apparently within the footing of tank G-9. 15-GP8 is apparently upgradient of tank G-9, so the source of the 100 ppb TPV is uncertain.

Three PAH compounds and lead were detected in the standard lab analyses of 15-GP6. The PAH compounds were detected at relatively low levels. Lead was elevated in the total lead sample (668 ppb), but much lower in the dissolved lead sample (25.8 ppb), probably because the lead is not in the groundwater itself but is sorbed to the soil particles collected with the water sample. Dynamac split this sample and analyzed for total metals, volatiles, semivolatiles, and potentially other analytes. These results may provide a more complete picture of the high contamination at this location.

Health and Environmental Assessment

Groundwater concentrations that exceeded federal MCLs and proposed MCLs are listed in Table 4-7-2. Groundwater in 15-GP6 exceeded MCLs or proposed MCLs for lead, benzene, ethylbenzene, toluene, and total xylene. Groundwater in 15-GP2 and 15-GP3 was above the MCL of 5 ppb for benzene. The MCL for lead of 15 ppb was exceeded by the dissolved lead sample and by the total lead sample from 15-GP6.

Fate and Transport

The patterns of contamination are consistent with the northeasterly groundwater flow direction indicated by the 1982 R. E. Wright data. The presence of BTEX contamination only in the center of the site may indicate that those releases were more recent than the others or that they were more voluminous, or both. BTEX is probably absent over a wider area because it has broken down or volatilized out of the soil in these areas, leaving only the more persistent fuel fraction. This is expected considering the shallow depth to water and the age of the tank farm operations.

Soils probably are contaminated with free product where it is present as a distinct layer on the water table. The extent of free product and of contaminated soil areas is unknown. No contaminated surface soils were observed during the investigation, so the potential for offsite transport of contaminated soils during storm events appears low.

The shallow ditch that crosses the center of the site (see Figure 4-7-3) drains south to the wetlands area but has no other outlet. There were no fuel odors during the ecological review of the ditch or the wetlands and no signs of stress were noted in either area. Because no apparent pattern exists with the contamination and the drainage, the potential for offsite migration of contaminated surface water appears low.

Table 4-7-2
CONSTITUENTS IN GROUNDWATER AT SITE 15
THAT EXCEEDED POTENTIALLY APPLICABLE FEDERAL STANDARDS

Analyte	Sampling Point	Concentration	MCL	MCLG	Proposed RCRA Action Levels
Benzene	15-GP2 15-GP3 15-GP6	6.3 86 16,000	5	NA	NS
Ethylbenzene	15-GP6	13,000	700	700	4,000
Toluene	15-GP6	6,900	1,000	1,000	10,000
Total Xylene	15-GP6	22,000	10,000	10,000	70,000
Lead Total Dissolved	 15-GP6 15-GP6	 25.8 668	TT (at tap)	0 (at tap)	MCL

NS = No standard available
NA = Not applicable
MCLs and MCLGs based on December 1992 Drinking Water Regulations and Health Advisories.
TT = The lead MCL is based on sampling at the tap and, therefore, does not apply.

WDCR709/038.51

OC-00175-03.13-12/01/93

Recommendations

Because the area believed to be downgradient of the worst contamination found during the RFI is uncharacterized, the RFI should be continued, with an expanded *in situ* groundwater sampling program. *In situ* sampling was useful as a quick screening technology during the RFI and should provide a quick assessment of additional contaminated areas. However, in light of the substantial contamination, a number of monitoring wells should be installed also. Their locations should be based on the *in situ* results.

Although characterization is not complete, the area near 15-GP6 clearly is highly contaminated and free-product fuel is present in the center of the site. The extent of free-product should be determined during the next phase of work. The initiation of free product recovery in the center of the site is recommended, either as part of the next phase of characterization or sooner. No soil sampling is proposed because the groundwater investigation will include observations of the extent of free product, which will also indicate areas of soil contamination.

Site 16—Pesticide Storage Area

Site Location and History

Site 16 consists of two different pesticide storage areas. One area is adjacent to the pesticide shop at Building 821 in the Public Works Compound and the other is at the Golf Course Maintenance Shop (see Figures 4-8-1 and 4-8-2). The IAS states that rinsewater from the pesticide-mixing tank was discharged directly onto the ground at the pesticide shop near Building 821 between 1968 and 1982 (RGH, 1984). The pesticides used at this location include 2,4-D, 2,4,5-T, baygon heptachlor, malathion, dursban, nibaryl, aldrin, chlordane, bromacil, warfarin, and DDT. About 2,000 pounds of active ingredients of these pesticides were mixed each year at this site. Contamination may have resulted from washing out pesticide containers and equipment during the 15-year life of the pesticide shop. The washout water discharged to the ground was estimated to contain less than 30 pounds of pesticides over the 15-year period (RGH, 1984).

The pesticide area at the NAS Oceana Golf Course has existed since 1956 (RGH, 1984). Pesticides were stored in the Golf Course Barn, Building 798 (RGH, 1984). Materials stored in the barn include 100 to 120 lb/year of fungicides, including Daconil, Chipco 26019, and dursban; 80 to 90 lb/yr of herbicide, including Daconte 6; and 5 to 10 lb/yr of Oursban, an insecticide (RGH, 1984). Since 1982, 55-gallon drums of pesticides drained from the spray tank have been removed by the Public Works as part of the hazardous waste pickup program (RGH, 1984). Before 1982, residual pesticides were rinsed over a concrete rinsing pad outside Building 798 (RGH, 1984). This rinsewater flowed into a shallow drainage ditch adjacent to Building 798.

Past Investigations and RFI Site Activities

There has been no environmental sampling at either of the two areas of Site 16. The basis for including these two areas in the RFI was information on waste handling gathered during the RFA. In the RFA, Navy personnel stated that rinsewater from the pesticide mixing tank was discharged directly onto the ground near Building 821 and that residual pesticides were rinsed over a concrete rinsing pad outside Building 798 (RGH, 1984).

The purpose of the RFI activities was to characterize the soils in the two areas used for pesticide storage. The field investigation examined the soils at both of the Site 16 storage areas. Four samples were collected at Building 821 (16-SS1 through 16-SS4) and four soil samples (16GC-SS1 through 16GC-SS4) were collected at Building 798. All samples were collected at a depth of 1.0 to 2.0 feet, as specified in the work plan. CH2M HILL personnel selected sample locations on the basis of the visual signs of contamination. All samples were analyzed for pesticides, organophosphorus pesticides, and herbicides. In addition, 16-SS1, 16-SS2, 16GC-SS1, and 16GC-SS2 were analyzed for copper, arsenic, and lead. The locations of all RFI samples are shown in Figures 4-8-1 and 4-8-2.

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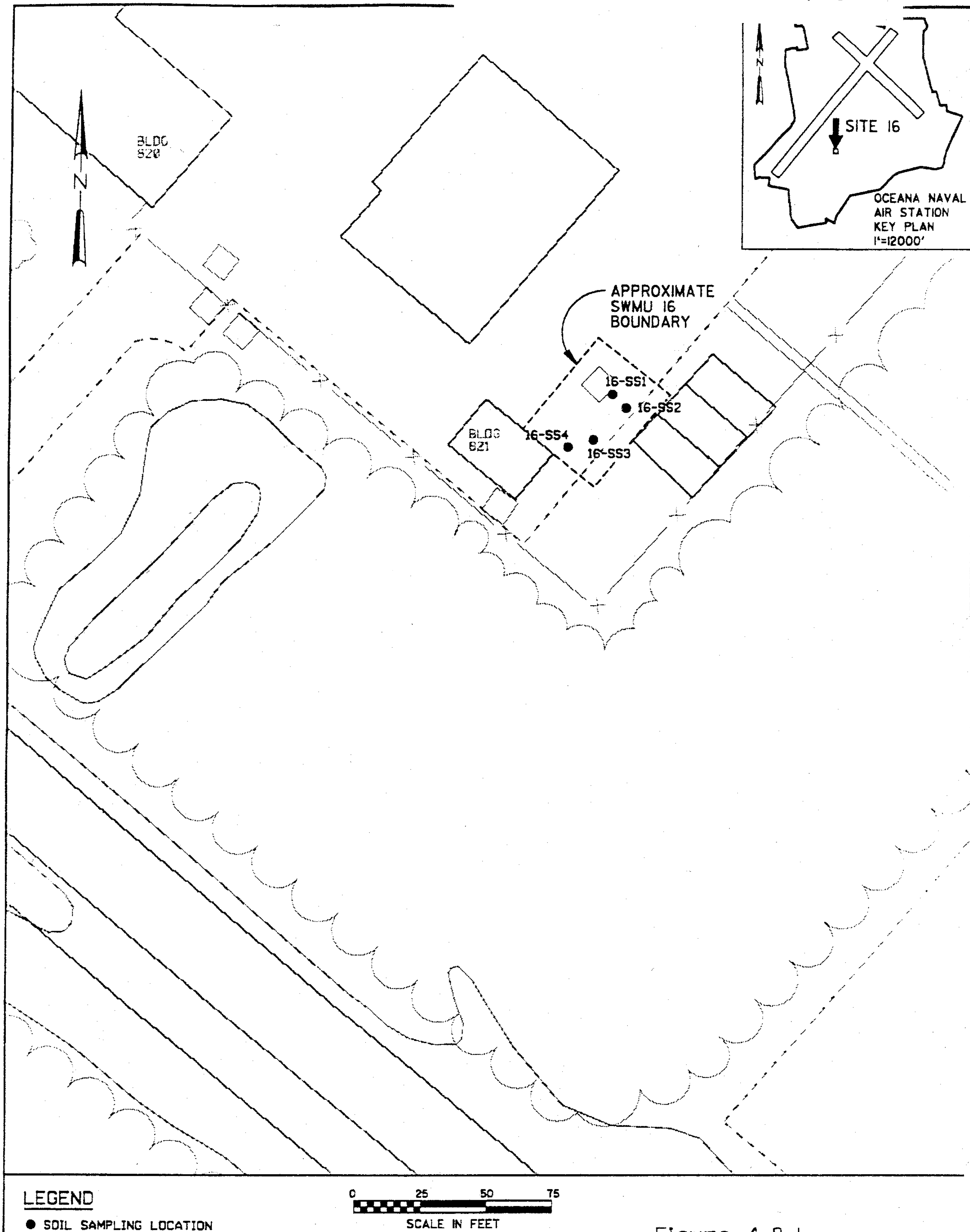

Figure 4-8-1
RFI SAMPLING LOCATIONS
AT SITE 16
FEBRUARY 1993

CH2M HILL

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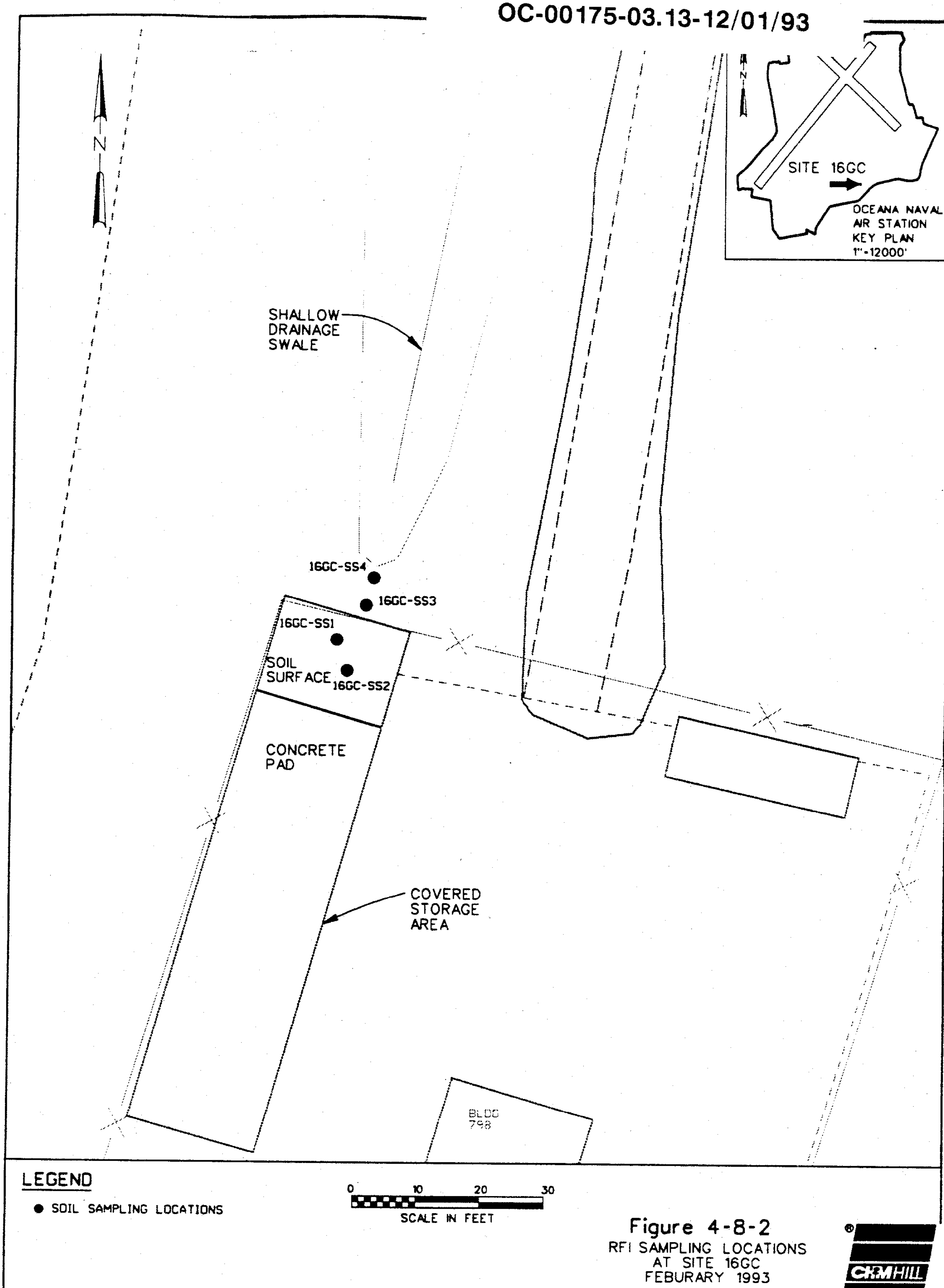

Figure 4-8-2
RFI SAMPLING LOCATIONS
AT SITE 16GC
FEBURARY 1993

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Environmental Setting

The pesticide storage area behind Building 821 includes a small undeveloped lot adjacent to the pesticide shop (see Figure 4-8-1). This area is approximately 1/2 to 1 acre. Beyond the gravel lot of the Building 821 pesticide area, the study area is mostly forested. During the study, most of the vegetation in the area closest to Building 821 was being removed and a small area was being excavated as part of construction of an extension to a nearby building. The site is very flat except for a small pond or ditch near the edge of the forested area on the north side of the study area. Soil or gravel covers the entire study area. Figure 4-8-3 is an ecological map of the area encompassing the Building 821 pesticide site, as well as Sites 21, 23, and 24. The ecology of these sites is presented together because of their proximity.

Ecology

Surface Water Resources. The ditch near Building 821 is approximately 20 feet wide by 50 feet long and 1 foot deep. A culvert is on the southwest end of the ditch. At the time of the field survey it appeared to be blocked. A very small, shallow swale flows into the ditch in the direction of 8th Street. An outlet for the ditch was not found at the time of the assessment. The closest surface stream is approximately 300 meters southwest of Building 820.

Wetlands. No wetlands were identified at SWMU 16.

Vegetation. The forested area is dominated by tulip poplar, American beech, paw paw, giant cane, sweetgum, and southern red oak. Lawn grasses surrounded the forested area along 8th Street and the access driveway.

Wildlife. The area is very small and probably does not support many species of mammals or birds. No mammals, or their signs were observed at this location. Crows and European starlings were seen flying overhead. Green frogs were abundant in the ditch, as were tadpoles. In addition, habitat existed that could support a small rodent and rabbit population.

Geologic and Hydrogeologic Characteristics

The geology cannot be described beyond the knowledge gained from soil sampling. Near Building 821, the soil samples indicate that the shallow samples are sandy, lean clays. At the golf course pesticide shed, the shallow soils are sandy silts to sandy lean clays. There is no hydrogeological information about this site.

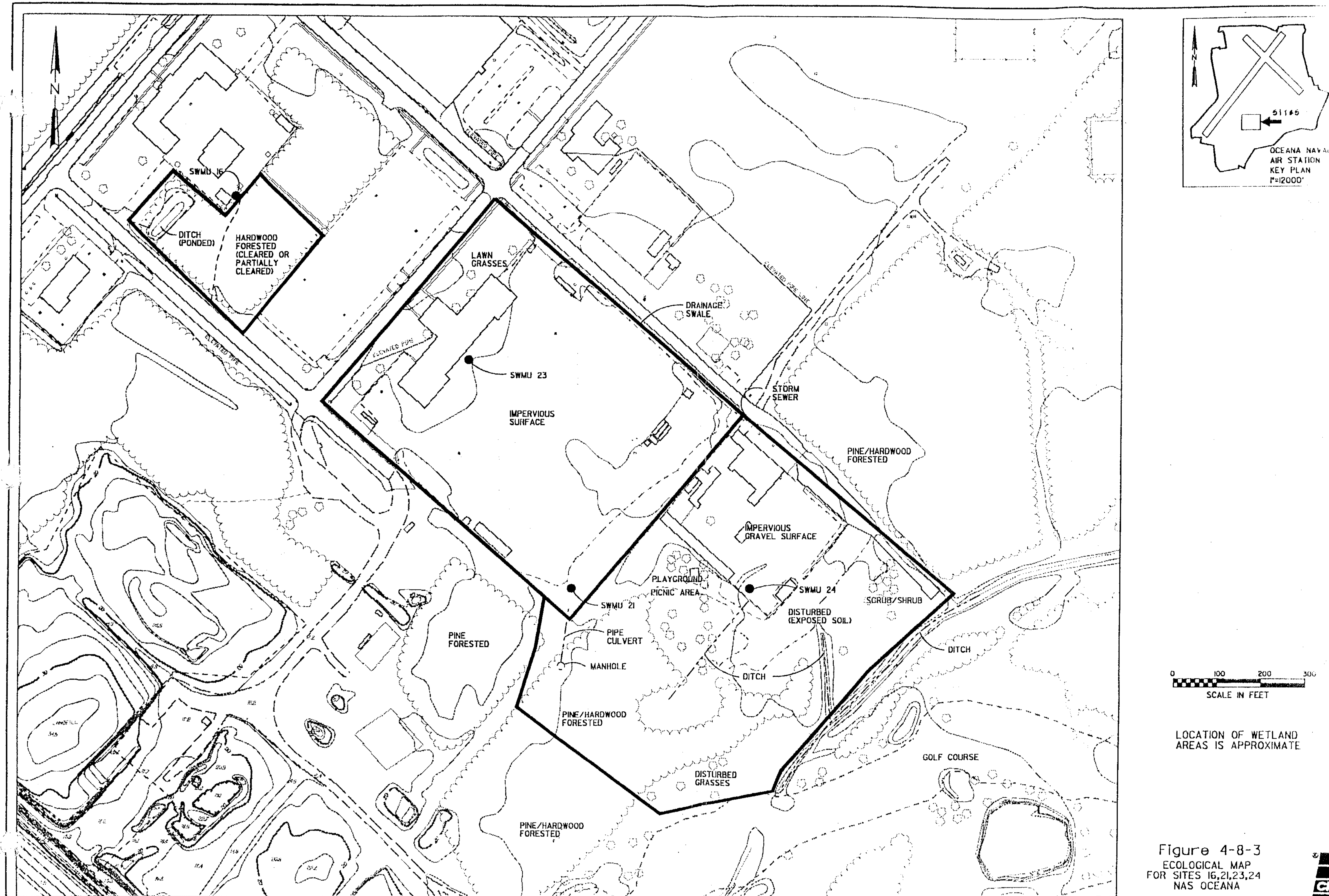

Figure 4-8-3
ECOLOGICAL MAP
FOR SITES 16,21,23,24
NAS OCEANA

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Contamination and Extent

The organic and inorganic results provided by the analytical laboratory are presented in Tables 4-8-1 and 4-8-2. The contamination and extent at each of the two locations comprising Site 16 will be discussed separately.

Building 821. Five pesticide compounds were detected adjacent to Building 821: dieldrin, 4,4'-DDE, 4,4'-DDD, 4,4'-DDT, and chlordane. All five pesticides were detected in all four samples, except dieldrin, which was not detected in 16-SS3. The pesticide concentrations were consistently highest in 16-SS2 and 16-SS3. Chlordane concentrations were 260 ppb in both samples, while 4,4'-DDD registered 100 ppb and 200 ppb, respectively. 4,4'-DDT was detected in 16-SS1 and 16-SS2 at concentrations of 170 ppb and 200 ppb.

Neither organophosphorus pesticide compounds nor herbicide compounds were detected in any soils samples adjacent to Building 821; however, lead, copper, and arsenic were detected in 16-SS1 and 16-SS2.

Golf Course Support Facilities. Analysis for organic contaminants in the soils at the golf course facility detected chlorinated pesticide, organophosphorus pesticide, and herbicide compounds. The chlorinated pesticides 4,4'-DDE, 4,4'-DDD, 4,4'-DDT were found in 16GC-SS1 and 16GC-SS2, and chlordane was detected in 16GC-SS4. The herbicide Dicamba was detected in 16GC-SS1 (31 ppb) and 16GC-SS4 (51 ppb). The organophosphorus pesticide, Chlorpyrifos, was detected in SS1 (270 ppb), SS2 (1,200 ppb), and SS3 (160 ppb).

Lead, copper, and arsenic were detected in 16GC-SS1 and 16GC-SS2. The concentrations were highest in 16GC-SS2 where lead, copper, and arsenic were detected at 22,100 ppb, 10,800 ppb, and 22,000 ppb, respectively.

Health and Environmental Assessment

The contaminants detected in the soils at Site 16 are present in low enough concentrations that they do not appear to pose a threat to human health. All pesticide and metal concentrations are well below the proposed RCRA action levels listed in Table 4-8-3. No human-health standards are available for chlorpyrifos, dicamba, copper, or lead and concentrations of these pesticides are all below risk-based screening concentrations, which are in the ppm range, that were calculated by toxicologists at the EPA (Smith, 1993).

No organics or inorganics exceeded federal ecological limits at Site 16. Arsenic and lead were the only potential ecological contaminants of concern detected. The maximum concentrations of arsenic and lead detected in Site 16 soils were 22,000 ppb and 22,100 ppb, respectively. These concentrations were higher than background concentrations for

Table 4-8-1
ORGANIC COMPOUNDS IN SOILS AT SITE 16, PESTICIDE STORAGE AREAS
February 1993
(All data in μg/kg)

	Building 821					Golf Course Area			
	16-SS1[a]	16-SS2		16-SS3	16-SS4	16GC-SS1	16GC-SS2	16GC-SS3	16GC-SS4
		Initial	Duplicate						
Pesticide Compounds									
Dieldrin	0.78	21	NA	*	3.9	*	*	*	*
4,4'-DDE	2.1	17	NA	15[j]	10	*	*	23	26
4,4'-DDD	8	100	NA	200	34	*	*	15[j]	14
4,4'-DDT	5.2	170	NA	200	12	*	*	9.2[j]	12
Chlordane	21	260	NA	260	180	*	*	*	40
Organophosphorous Pesticide Compounds									
Chlorpyrifos	*	*	*	*	*	230	1,200	160	*
Herbicide Compounds									
Dicamba	*	*	*	*	*	31	*	*	51

Notes:
Site 16 consists of 2 pesticide storage areas. One is located adjacent to Building 821 and the other is at the Golf Course Support Facility.
All pesticide, organophosphorous pesticide, and herbicide compounds not listed were analyzed but were not detected in any samples. All soil samples were collected for 1.0 to 2.0 feet.
QC Sampling: 16-SS30 is a duplicate of 16-SS2.
[a]The herbicide and organophosphorous pesticide results were qualified as estimated during the data validation process because the extraction holding times were exceeded.
NA - Not analyzed.
* Compound analyzed but not detected.
[j] Estimated value. The compound was present below the stated quantitation limit.

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Table 4-8-2
INORGANIC COMPOUNDS IN SOILS AT SITE 16, PESTICIDE STORAGE AREAS
February 1993
(All data in μg/kg)

Analyte	Building 821					Golf Course Area			
	16-SS1	16-SS2		16-SS3	16-SS4	16GC-SS1	16GC-SS2	16GC-SS3	16GC-SS4
		Initial	Duplicate						
Arsenic*	2,400[b]	2,900	2,900	NA	NA	11,900	22,000	NA	NA
Copper	4,800	7,000[n]	9,000[n]	NA	NA	6,800[n]	10,800[n]	NA	NA
Lead	8,400	9,100	10,800	NA	NA	11,800	22,100	NA	NA

Notes:
Arsenic, Copper, and Lead were the only metals analyzed as part of this sampling program.
Site 16 consists of 2 pesticide storage areas. One is located adjacent to Building 821, and the other is at the Golf Course Support Facilities.
All soil samples were collected from 1.0 to 2.0 feet.
QC Sampling: 16-SS30 is a duplicate of 16-SS2.
NA - Not analyzed.
[b]The reported value was less than the CRDL, but greater than or equal to the IDL.
[n]Spiked sample recovery not within control limits.
*The instrument detection limit for arsenic is 170 μg/kg. The CRDL is 2,430 μg/kg.

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Table 4-8-3
CONSTITUENTS IN SOIL AT SITE 16 AND 16GC COMPARED AGAINST POTENTIALLY APPLICABLE FEDERAL STANDARDS

Compound	Media Detected	Concentration (ppb)	Eastern United States Background	RCRA Action Level	Risk-Based Concentration Commercial/ Industrial (noncarcinogenic)*
Arsenic	Soil	22,000 a	4,800	80,000	310,000
Lead	Soil	22,100 a	14,000	NS	NS
4,4'-DDE	Soil	26 a	NA	2,000	8,400
4,4'-DDD	Soil	200 a	NA	3,000	12,000
4,4'-DDT	Soil	200 a	NA	2,000	8,400
Dieldrin	Soil	21 a	NA	40	180
Chlordane	Soil	260 a	NA	500	2,200
Chloropyrifos	Soil	1,200 a	NA	NS	3,100,000
Dicamba	Soil	51 a	NA	NS	31,000,000

Notes:
a = Maximum concentration from all sample locations at Site 16
*Risk-based concentrations from Smith (1993). Note that soil concentrations also are below noncarcinogenic standards for residential soil (23,000 ppb). The mean concentration of arsenic in soil in the eastern United States (4,800 ppb; Shacklette and Boerngen, 1984) is higher than the carcinogenic standard for both residential (680 ppb) and commercial/ industrial soil (1,600 ppb)
NA = Not applicable
NS = No standard

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arsenic and lead in the eastern United States (Shacklette and Boerngen, 1984), which are 4,800 ppb and 14,000 ppb, respectively. The RCRA action level for arsenic, which is based on noncarcinogenic human and ecological effects rather than background, is 80,000 μg/kg. Site 16 arsenic concentrations are well below the proposed RCRA action level and also are below commercial, industrial, and residential noncarcinogenic RBCs. The mean concentration of arsenic in the eastern United States is above carcinogenic RBCs. There is no proposed RCRA action level for lead. The potential effects of arsenic and lead to environmental receptors is discussed in Appendix A.

Fate and Transport

The solubility of the detected chlorinated pesticides is low and all have a strong tendency to adsorb to soil particles. Therefore, the primary transport mechanism is soil erosion. Because the contamination was detected at a depth of 1.0 to 2.0 feet, the potential for soil erosion of known contamination is limited. However, the contamination at this depth suggests that soils from 0 to 1.0 foot also may be contaminated and these soils could erode. In addition, infiltration through the unsaturated zone to the water table could act as a transport mechanism for these contaminants. 16GC-SS1 and 16GC-SS2 are located beneath a shed roof and are sheltered from the rain; therefore, infiltration is reduced. It is noteworthy that the sampling locations at the Golf Course Support Facility (16GC-SS1 through SS4) are close to a shallow drainage ditch. During times of heavy precipitation, soil could be eroded and flow into this ditch. However, because this is not a strong drainage feature and much of the ditch is covered with grass, erosion may not be a significant transport mechanism.

Recommendations

Because contaminant concentrations were low, no future RFI or CMS activities are recommended at either Site 16 location.

WDCR711/018.51

Site 18—Hazardous Waste Storage, Building 204

Site Location and History

Site 18 consists of two hazardous waste accumulation areas near Building 200 adjacent to B Avenue (see Figure 4-9-1). The accumulation area closest to Building 200 is approximately 15 by 25 feet, and stores fewer than 10 drums. The walls, roof, and entrance way of the accumulation area are secured by a chain-link fence. Fifty-five-gallon drums rest on a raised concrete slab floor. Under the current hazardous waste management program, they are stored for a period of less than 90 days. During the visual site inspection of a second older storage shed nearby, no release controls were observed, and there is no documentation of releases; however, soil staining was observed. The newer hazardous waste storage shed has existed for at least 10 years and was in use at the time of the VSI. The shed may date to 1981 when Public Works initiated the hazardous waste pick-up program.

The RFA noted that materials typically stored at the shed may include any of the following: double-bagged empty oil and paint cans; double-bagged oily rags; and drums of oil, paint thinner, paint remover, jet fuel, solvents, asbestos, PD 680, hydraulic fluid, freon, neutralized battery acid, and electric coolant oil.

Past Investigations and RFI Site Activities

There has been no previous environmental sampling at Site 18. According to the RFA, soil staining around this hazardous waste storage shed was observed during the visual site inspection. For this reason, Site 18 was included in the RFI.

The purpose of the RFI activities at this site was to characterize the soils to determine if contamination has occurred. The field investigation consisted of collecting two soil samples (18-SS1 and 18-SS2) near the storage area. The samples were collected from 0.5 to 1.0 feet. Both samples were analyzed for Appendix IX parameters. The RFI sample locations are shown in Figure 4-9-1.

Environmental Setting

Most of the study area is in the flight line. Areas off the flight line that were included in the study are the parking lot and lawn surrounding Buildings 210 and 212.

Adjacent to the storage unit, the site is flat, but slopes gently toward a shallow swale on the side of B Avenue a few feet to the southeast. Ground cover consists mostly of concrete and asphalt parking lots, driveways and road. A thin layer of soil and grass covers the concrete slope within 2 to 3 feet of the storage unit fence. Lawn areas, separated from the access road by a cement curb, surround the buildings in the study area.

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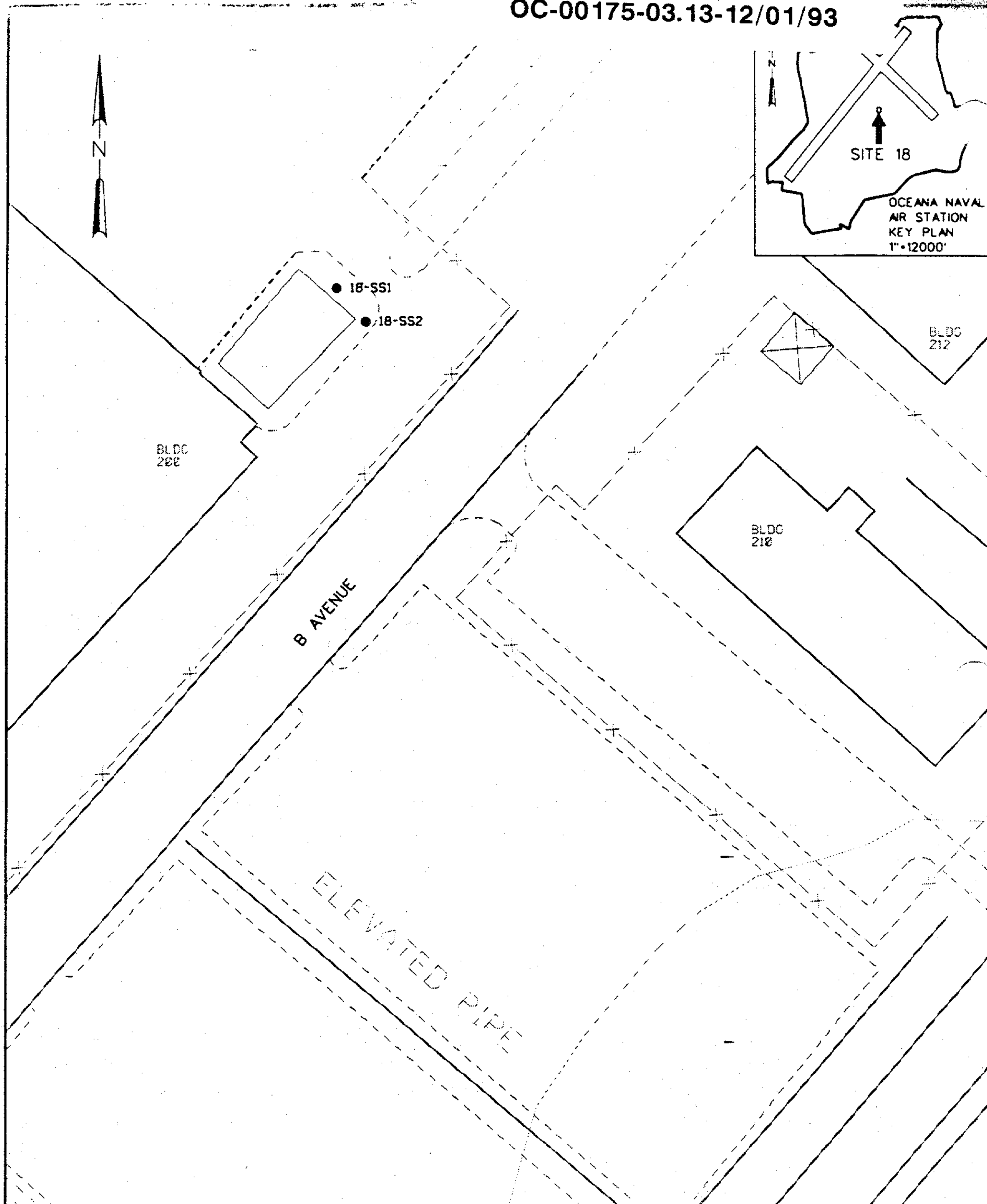

LEGEND

● SOIL SAMPLING LOCATION

0 25 50 75
SCALE IN FEET

Figure 4-9-1
RFI SAMPLING LOCATIONS
AT SITE 18
FEBRUARY 1993

CH2M HILL

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Aside from the shallow ditch on the shoulder of B Avenue, the closest ditch to Site 18 is approximately 250 feet to the northeast. There are no wetlands near the site.

Two species of trees were identified in this area: blackjack oak and sweetgum. Other vegetation in the study area included lawn grasses and unidentified cultivated shrubs. No species of birds or other wildlife were observed.

The geology of this site cannot be characterized because no borehole logs exist. Two soil samples were collected from 0.5 foot to 1.0 foot. On the basis of the sampling, the shallow soil is a sandy silt underlain by a clean, poorly-graded, coarse sand. This sand appears to be a by-product of the construction that has occurred in the general vicinity of the site. No information is available on the hydrogeology of the site.

Contamination and Extent

The analytical laboratory results of soil sampling at Site 18 are presented in Tables 4-9-1 and 4-9-2. The organic analyses detected very low concentrations of chlorinated pesticides and VOCs, and several SVOCs. No organophosphorus pesticides, herbicides, or dioxins/furans were detected.

The only VOC detected was xylene, which was detected below the quantitative detection limit in 18-SS2 (2 ppb). Two pesticides, 4,4'-DDD and 4,4'-DDT, were detected in 18-SS1 below quantitative detection limits, at concentrations of 11 ppb and 8.6 ppb, respectively. Fourteen SVOCs were present in both 18-SS1 and 18-SS2. The compounds detected are all constituents of oil and fuels; however, the exact origin of the contamination is not known. Semivolatile contamination generally appeared worse in 18-SS2 than in 18-SS1. Benzo(a)anthracene, benzo(a)pyrene, and dibenz(a,h)anthracene were the only SVOCs that exceeded established health criteria. A comparison of contaminant concentrations versus applicable health standards follows in the HEA.

The inorganic analyses of the Site 18 soils detected low concentrations of heavy metals near the detection limit, including arsenic, beryllium, cadmium, chromium, copper, mercury, and nickel.

Health and Environmental Assessment

An assessment of the Site 18 analytical results indicates that several compounds exceeded established health standards. Table 4-9-3 compares contaminant concentrations to applicable federal standards. Benzo(a)anthracene, benzo(a)pyrene, and dibenz(a,h)-anthracene were substantially above health-based guidelines for carcinogens, particularly in 18-SS2.

ORGANIC COMPOUNDS IN SOILS AT SITE 18
February 1993
(All data in µg/kg)

Analyte	18-SS1[a]	18-SS2[a]
Volatile Compounds		
Methylene Chloride	8[b]	9[b]
Xylene (Total)	*	2[j]
Semivolatile Compounds		
Phenanthrene	110[j]	700[j]
Di-n-butylphthalate	74[bj]	240[bj]
Fluoranthene	330[j]	4,400
Pyrene	330[j]	4,300
Butylbenzylphthalate	48[j]	270[j]
Benzo(a)anthracene	240[j]	2,600
Chrysene	290[j]	3,400
Bis(2-ethylhexyl)phthalate	260[j]	1,300
Benzo(b)fluoranthene	420	4,900
Benzo(k)fluoranthene	400	3,600
Benzo(a)pyrene	460	4,800
Indeno(1,2,3-cd)pyrene	420	2,700
Dibenz(a,h)anthracene	100[j]	670[j]
Benzo(g,h,i)perylene	490	2,900
Pesticide/PCB Compounds		
4,4'-DDD	11[j]	*
4,4'-DDT	8.6[j]	*
Organophosphorous Pesticide Compounds	*	*
Herbicide Compounds	*	*
Dioxins/Furans	*	*

Notes:
All samples at Site 18 were analyzed for Appendix IX parameters.
All volatile, semivolatile, pesticide/PCB, organophosphorous pesticides, herbicides, and dioxin/furan compounds not listed in the table above were analyzed for but not detected in any samples.
*Compound analyzed but not detected
[a] The herbicide results were qualified as estimated during the data validation process because the extraction holding times were exceeded.
[b] The analyte is found in the associated blank as well as the sample
[j] Indicates an estimated value

Table 4-9-2
INORGANICS IN SOILS AT SITE 18
February 1993
(All data in mg/kg)

Analyte	18-SS1	18-SS2
Aluminum	8,690	8,660
Antimony	<3.7	<3.6
Arsenic	3.0	2.8
Barium	33.9 B	33.9 B
Beryllium	0.29 B	0.25 B
Cadmium	1.6	2.8
Calcium	2,180	1,380
Chromium	14.1	30.9
Cobalt	2.8 B	2.7 B
Copper	9.7	38.7
Iron	8,220	8,820
Lead	24.2	113
Magnesium	613 B	784 B
Manganese	70.5	54.1
Mercury	0.10	0.13
Nickel	5.4 B	7.7 B
Potassium	275 B	280 B
Selenium	<0.42	0.59 B
Silver	<0.45	<0.44
Sodium	188 B	226 B
Thallium	<0.53	<0.51
Vanadium	13.0	14.3
Zinc	36.0	121
Cyanide	<0.16	<0.16

Notes:
< The constituent was not detected at this instrument detection limit (IDL).
B The reported value was less than the Contract Required Detection Limit, but greater than or equal to the IDL.

Table 4-9-3
ORGANIC AND INORGANIC CONSTITUENTS DETECTED IN THE SOILS AT SITE 18
THAT EXCEEDED POTENTIALLY APPLICABLE FEDERAL STANDARDS OR CRITERIA
February 1993
(All data in ppb)

Compound	Location Detected	Concentration	Health Based Criteria for Carcinogens	Health Based Criteria for Systemic Toxicants	Proposed RCRA Action Levels	Eastern United States Soil Mean Concentration[c]
Benzo(a)anthracene	18-SS1 18-SS2	240 j 2,600	224	NS	NS	NS
Benzo(a)pyrene	18-SS1 18-SS2	460 4,800	60.9	NS	NS	NS
Dibenz(a,h)anthracene	18-SS1 18-SS2	100 j 670 j	14.3	NS	NS	NS
Beryllium	18-SS1 18-SS2	290 b 250 b	143	NS	NS	550
Copper	18-SS1 18-SS2	9,700 38,700	NS	NS	NS	13,000
Lead	18-SS1 18-SS2	24,200 113,000	NS	NS	NS	14,000
Mercury	18-SS1 18-SS2	100 130	NS	NS	20,000	81
Selenium	18-SS2	590	NS	NS	NS	300
Zinc	18-SS1 18-SS2	36,000 121,000	NS	NS	NS	40,000

Notes:
Only the compounds which were detected and exceeded standards are listed in the table above.
The Health Based Criteria for Carcinogens and for Systemic Toxicants were extracted from the RFI Guidance Document EPA 530/Sw-89-031.
The proposed RCRA Action Levels were listed in the Federal Register dated 27 July 1990.
NS = No standard has been established.
b = The reported value was less than the Contract Required Detection Limit, but greater than the Instrument Detection Limit (IDL).
j = Indicates an estimated value because the concentration is below the accurately quantitative detection limit.
c = See Appendix A for discussion.
ND - Not detected.

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Benzo(a)anthracene was present at concentrations of 240 ppb (18-SS1) and 2600 ppb (18-SS2) versus a standard of 224 ppb. Benzo(a)pyrene concentrations of 460 ppb and 4800 ppb respectively, exceeded the established standard of 60.9 ppb; and dibenz(a,h)-anthracene concentrations of 100 ppb and 670 ppb, respectively exceeded the standard of 14.3 ppb. Benzo(b)fluoranthene, indeno(1,2,3-cd)pyrene, and benzo(a)pyrene concentrations also exceeded the EPA Region III RBCs.

Beryllium concentrations were also considerably above the established criterion for carcinogens of 143 ppb. Beryllium concentrations were 290 ppb in 18-SS1 and 250 ppb in 18-SS2. As stated previously, it is unclear if beryllium is caused by site activities because it is so common at the RFI sites and is present in soil at an average concentration of 550 ppb in the eastern United States. Although the concentrations of arsenic as a carcinogen exceed the RBCs, the average arsenic concentration in soil in the eastern United States also exceeds the RBC. There are no proposed RCRA action levels for these four contaminants. No existing ecological standards were exceeded by the organic and inorganic concentrations detected at Site 18.

Five metals were detected at concentrations that were below health-based and ecological criteria but were above mean background concentrations for the eastern United States. Copper concentrations were 9,700 to 38,700 ppb versus a background of 13,000 ppb, lead was 24,200 to 113,000 ppb versus 14,000 ppb, mercury was 100 to 130 ppb versus 81 ppb, selenium was 590 ppb in 18-SS2 versus 300 ppb, and zinc was 36,000 to 121,000 ppb versus 40,000 ppb. None of these metals poses a known environmental threat.

Fate and Transport

The primary routes of migration from the site are for precipitation leaching through the shallow soils to the water table to transport the organic constituents to the groundwater system or for soil erosion to transport constituents to nearby drainages. Because the depth to which contamination extends is unknown, the potential for groundwater contamination is difficult to judge. Soil erosion at this site is expected to be limited because the contaminated soils were within areas where grass is well established and slopes are gentle.

Recommendations

Because the soil samples collected adjacent to the waste accumulation unit have constituents substantially above health-based criteria, additional characterization work to determine the extent of contamination is recommended. A program of soil and groundwater sampling is warranted. On the basis of the RFI results, analyses should be limited to semivolatiles and metals.

A review of RFA photos shows that the storage unit identified as RFA SWMU 3 during the RFA is a similar unit, 75 to 100 feet northeast of the storage unit where soil samples were collected during the RFI. The soils around the intended storage area should be sampled during the next phase of sampling as proposed in the RFI work plan. Site 18 should be expanded to encompass both waste accumulation units.

The waste accumulation unit that has already been sampled should be remediated after review of additional soil and groundwater sampling results from the next phase of sampling. If the results from the second waste accumulation unit also indicate contamination, this second unit also should be remediated pending any additional samples that may be necessary to complete characterization.

Site 19—Waste Oil Storage Area, Building 541

Site Location and History

Site 19 is near Building 541, which has been the Navy Exchange Gas Station since 1972 (RGH, 1984). This site is a 50 to 100 square foot area where waste oil; solvents; and transmission, brake, and hydraulic fluids were stored in 55-gallon steel drums directly on the ground (see Figure 4-10-1). The waste fluids and oil were generated by automobile repair and maintenance work at the station (RGH, 1984). An empty 55-gallon steel drum was observed in the grassy area immediately northeast of the gas station by CH2M HILL personnel during RFI activities. During the visual site inspection (VSI) completed as part of the RFA, inspectors noted soil staining and dead grass in this same area. During the VSI, only one drum was observed and there were no release-control mechanisms in place (RFA, 1988).

Past Investigations and RFI Site Activities

There has been no previous environmental sampling at Site 19. Because waste oil was stored in 55-gallon steel drums at this location, the site was included for study in the RFI. The purpose of the RFI activities was to characterize the soils and to determine if contamination has occurred. CH2M HILL personnel collected one soil sample (19-SS1) at a depth of 2.0 to 3.0 feet (see Figure 4-10-1). A sample also was collected from 0.5 to 1.0 foot; however, the deeper sample was submitted for analysis because field screening with the OVM showed higher readings from the deeper sample. The Site 19 soil sample was analyzed for VOCs, PAHs, total lead, and ~~total petroleum hydrocarbons~~ (TPH).

Environmental Setting

Because Sites 19 and 20 are within 200 feet of each other, they are within the same environmental setting. Consequently, the surrounding environment will be described as a unit. Figure 4-10-2 is a map showing the environmental setting of the two sites.

Sites 19 and 20 are flat areas including both developed and undeveloped land. A large forested area occurs northeast of the two sites. The portion of this forested area northwest of the elevated pipe is maintained as a recreational park with a jogging trail and picnic facilities. The ground cover in this area is cleared regularly but the trees remain. An area of lawn grasses approximately 50 feet wide separate the forest from the two sites. Much of the area adjacent to the buildings is developed. The ecological study area included the lawn, most of the forested area, and the developed area immediately south of the sites.

Site 19 is behind the Citgo gasoline station (Building 541), adjacent to a used tire storage area. The area is primarily flat with a gentle slope towards the woods. The developed portion of the study area is covered with concrete and asphalt parking lots, access roads, and storage areas. The forested area is flat. The soils in the area are poorly drained and classified as Acredale-Urban.

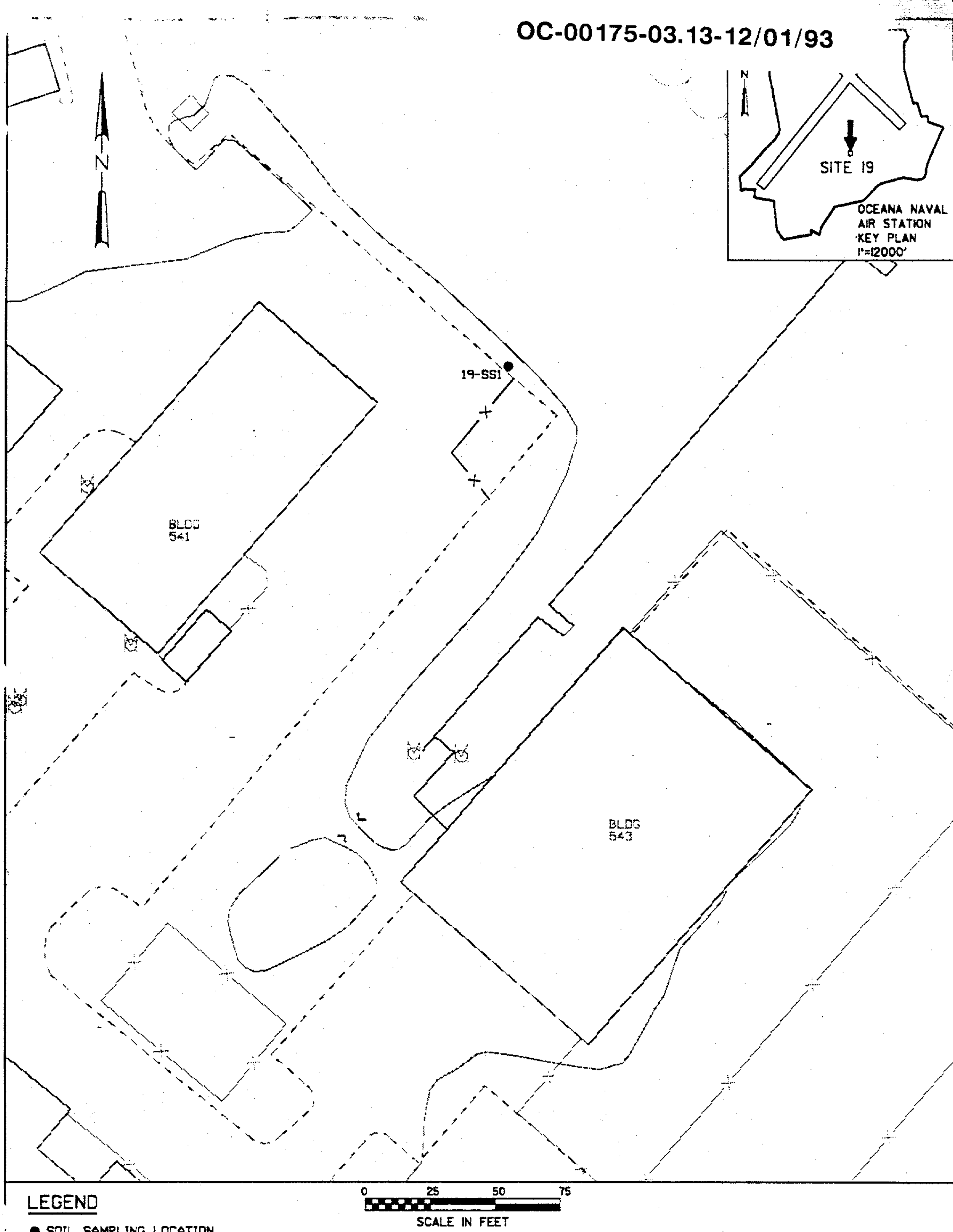

Figure 4-10-1
RFI SAMPLING LOCATIONS
AT SITE 19
FEBRUARY 1993

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Ecology

Surface Water Resources. No water resources were identified near the study area.

Wetlands. Most of the study area is made up of a mosaic of small wetland patches mixed with larger areas of uplands. Much of the forested area had saturated soil conditions at the time of the field survey, and is dominated by loblolly pine. This tree species, under natural conditions, occurs quite often in wetlands. In addition, portions of the area outside the forested area may also be wetlands, based on their low position on the landscape. Wetlands do not occur within the developed part of the site.

Vegetation. The forest appears to have been previously planted with loblolly pine, which has formed a very dense crown cover. A few American holly trees were observed in the forest also. The understory is very sparse, with greenbriar, Japanese honeysuckle, and giant cane among the few species occurring there.

The area outside the forest is planted in lawn grasses and is well maintained. No vegetation was observed in the developed part of the site.

Wildlife. Very few species of birds were identified in this area. Among the few species that were noted include yellow-rumped warblers, northern cardinals, American crow, and blue jays. Suitable habitat exists for downy and pileated woodpeckers, kinglets, and nuthatches, although these species were not observed in the area.

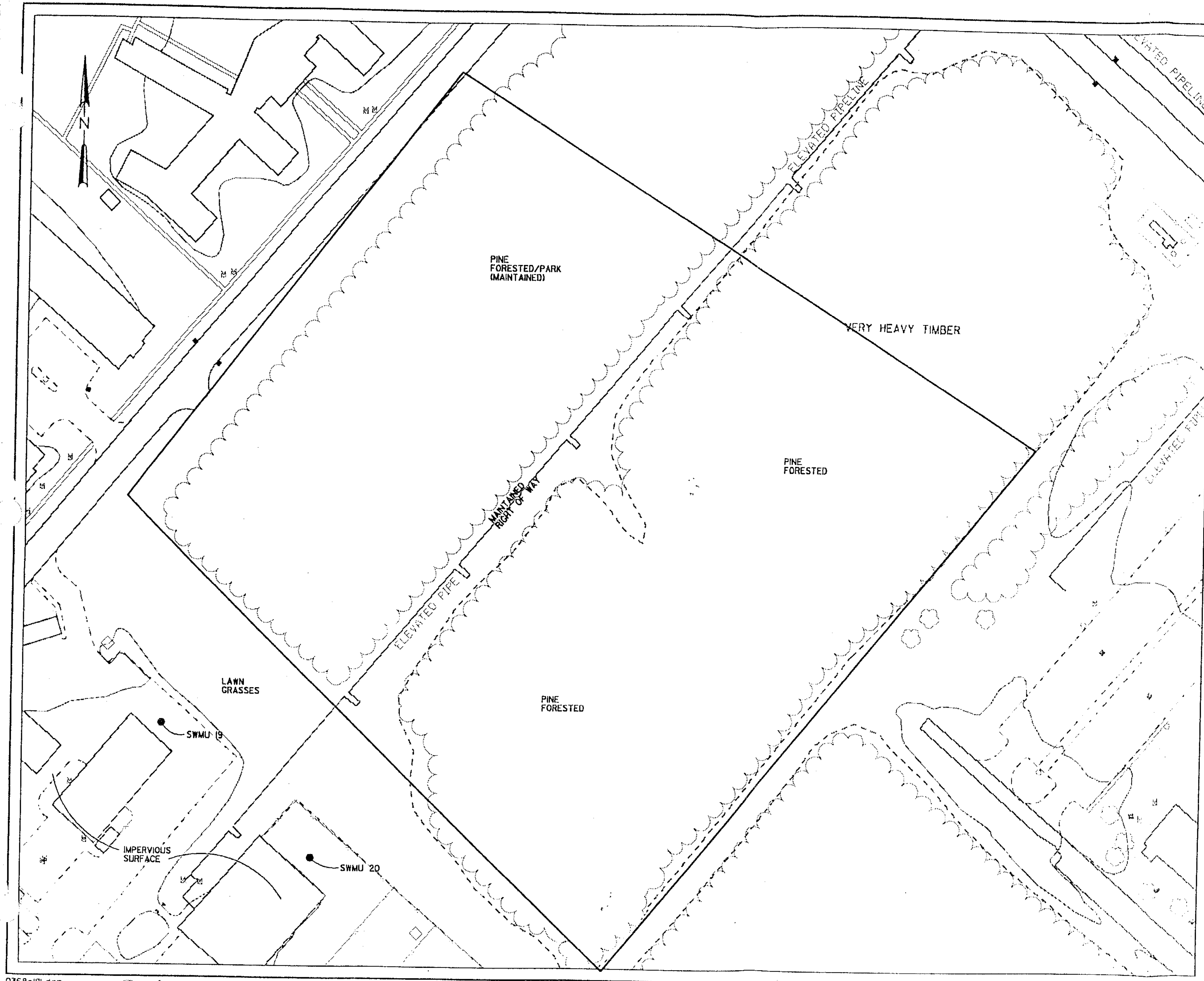
No mammals were observed in the study area. However, signs were identified that suggest a large white-tailed deer population exists in the area. Other mammals that may find suitable habitat in the area include squirrels, chipmunks, rodents, raccoon, and possibly fox.

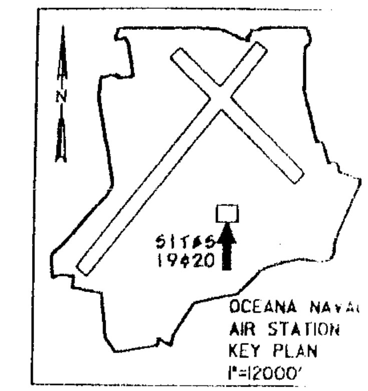
Geologic and Hydrogeologic Characteristics

One location at this site was sampled to a depth of 3 feet. On the basis of this sampling location, the shallow soils at this site are sandy silts underlain by silty sands. There is no information on the hydrogeologic conditions at this site; however, the prevailing groundwater flow direction over much of the eastern part of the base is to the southeast.

Contamination and Extent

Table 4-10-1 presents the analytical results for sample 19-SS1. Federal and state standards for the detected constituents are also shown. Xylene (10 ppb) was the only VOC detected in 19-SS1. Total lead was present at 86,300 ppb, and the total petroleum hydrocarbon concentration was 3,720,000 ppb. PAHs were not detected in 19-SS1.





0 50 100 150
SCALE IN FEET

LOCATION OF WETLAND
AREAS IS APPROXIMATE

Figure 4-10-2
ECOLOGICAL MAP
FOR SITES 19 & 20
NAS OCEANA

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Table 4-10-1
ORGANIC COMPOUNDS AND LEAD IN SOIL AT SITE 19
January 1993
(All data in μg/kg)

Analyte	Detection Limit	19-SS1	Health-Based Criteria for Carcinogens	Health-Based Criteria for Systemic Toxicants	Proposed Action Level	Virginia Soil Standard
Volatile Organic Compounds						
Methylene Chloride	5	24[b]	93,000	5×10^6	90,000	ND
Acetone	10	41[b]	ND	8×10^6	8×10^6	ND
Xylene (Total)	5	10	ND	2×10^8	2×10^8	ND
Total Lead	1,600	86,300	ND	ND	ND	ND
TPH	900	3,720,000	ND	ND	ND	100,000
Polynuclear Aromatics	50	*	N/A	N/A	N/A	N/A

Notes:
All volatile organic and polynuclear aromatic compounds not listed above were analyzed, but were not detected.
*Concentration below the detection limit.
[b]Compound not found in laboratory blank as well as sample.
ND = No Data
N/A = Not applicable
There was only one soil sample collected at this site.
The Health-Based Criteria for Carcinogens and the Health-Based Criteria for Systemic Toxicants were taken from the RFI Guidance Document, EPA 530/SW-89-031, dated May 1989. The proposed action levels were extracted from the federal register, Vol. 55, No. 145, dated July 27, 1990.

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Health and Environmental Assessment

Xylene contamination at Site 19 is well below both the RCRA health-based criterion for systemic toxicants and the proposed RCRA action level. No health-based criteria exist for lead in soil. The TPH concentration of 3,720,000 ppb greatly exceeds the Virginia guideline for TPH in soil (100,000 ppb). From an ecological perspective, the inorganic concentrations detected are well below background concentrations of elements in the eastern United States (Shacklette and Boerngen, 1984).

Fate and Transport

The depth to which contamination extends at Site 19 is unknown; however, the average depth to water is 8 to 10 feet over much of the east side of the base. Lead and TPH are generally persistent in soils. Infiltration may transport some petroleum constituents to the water table. Analytical data suggest that the volatiles known to be mobile in groundwater (e.g., benzene and toluene) may be largely absent in the soil at Site 19. Nonetheless, some constituents may have migrated to the groundwater soon after disposal.

Recommendations

Because the only sample collected at this site was considerably above the Virginia guidelines for TPH, additional RFI soil sampling at this site is recommended to determine the extent of TPH contamination. Groundwater also should be sampled to determine if it has been affected by oil disposal. Remediation of this site should proceed soon after the review of the results of additional sampling.

Site 20—Waste Oil Storage Area, Building 543

Site Location and History

Site 20 is on the grounds of Building 543, the Auto Hobby Shop (see Figure 4-11-1). The auto hobby shop is a self-help automotive garage where Navy personnel can work on their cars when off duty. It has been in existence since 1976 (RGH, 1984). Waste motor oil, hydraulic fluid, automatic transmission fluid, and PD680 and other solvents were stored in 55-gallon drums directly on the ground at this site. A strip of grass and bare ground approximately 150 feet long and 3 feet wide runs between the asphalt next to Building 543 and a larger grass area outside the fence.

Past Investigations and RFI Site Activities

During the visual site inspection for the RFA, soil staining, two 55-gallon steel drums, and dead grass were observed on a strip of grass approximately 150 feet long by 3 feet wide. Waste oil and other waste automobile fluids are stored in this area prompting its inclusion in the RFI.

The Navy sampled soils in 3 locations in the thin grass strip on July 14, 1992. One sample contained 940 mg/kg, but the other two contained less than 100 ppm of TPH. Some soil was excavated because of these results. An additional 4 samples were collected on September 30, 1992, to test for residual contamination. The September 1992 sample from a location adjacent to the 940 mg/kg location contained 47 mg/kg. All soil samples were analyzed for BTEX compounds, TPH, and TCLP lead.

The purpose of the RFI was to characterize the soils in the oil storage area east of Building 543. CH2M HILL personnel collected soil samples from four locations (20-SS1 through 20-SS4). The soils were screened by using an OVM to determine the sampling depth. The shallower sample, from 0.5 to 1.0 feet, was submitted for analysis at 20-SS1 and 20-SS3, and the 2.0 to 3.0 foot sample was submitted at 20-SS2 and 20-SS4. All four soil samples were analyzed for TPH, total lead, PAHs, and VOCs. The RFI soil sampling locations at Site 20 are shown in Figure 4-11-1.

Environmental Setting

Site 20 is flat, with developed asphalt and concrete areas, maintained lawn, and an adjacent forested area. It is adjacent to a parking lot where cars in disrepair are parked. Because Sites 19 and 20 are adjacent to each other, their environmental setting was studied as a unit. Refer to Figure 4-10-2 and the Site 19 environmental setting section for additional details.

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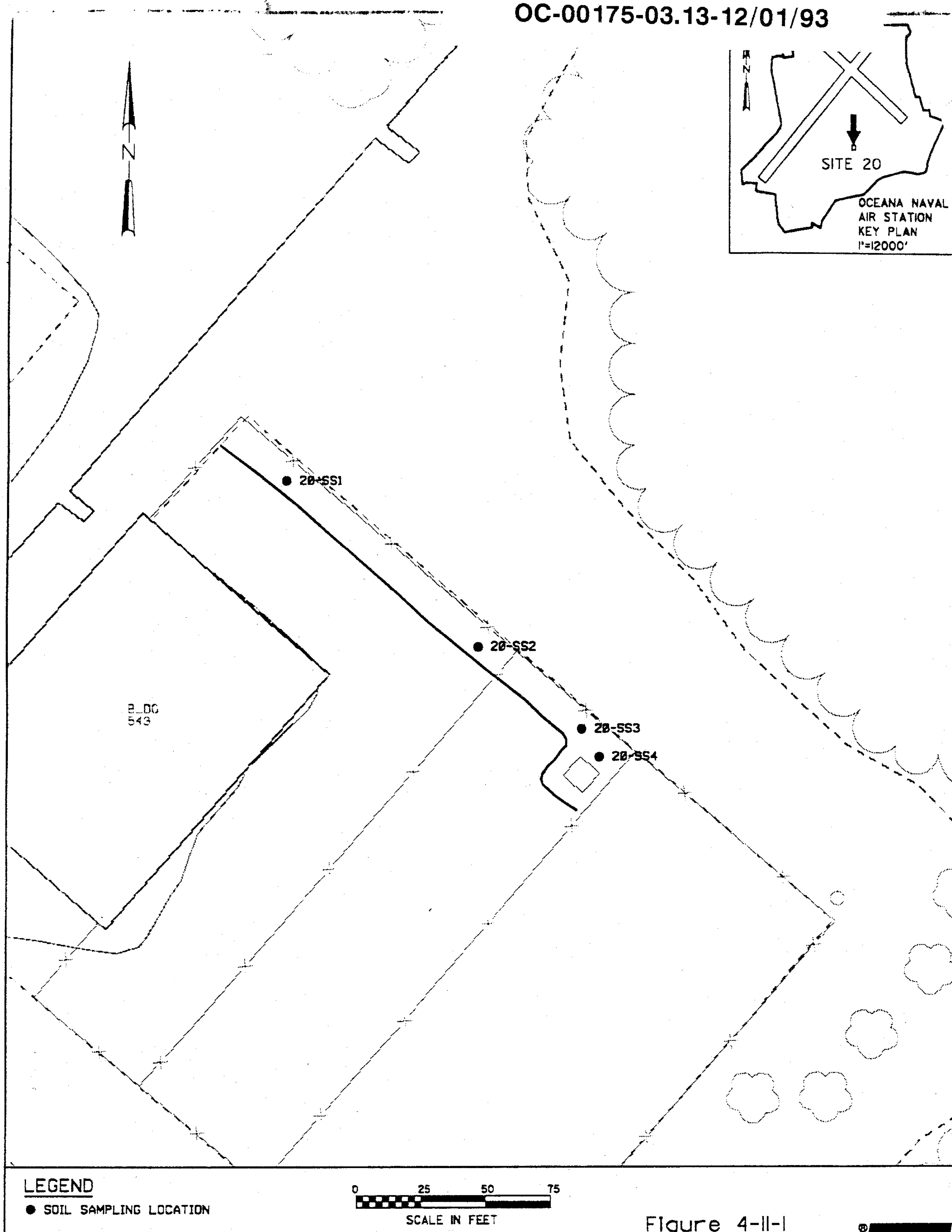

Figure 4-II-1
RFI SAMPLING LOCATIONS
AT SITE 20
FEBRUARY 1993

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Contamination and Extent

The analytical results provided by the CH2M HILL laboratory in Montgomery, Alabama, are presented in Table 4-11-1. Total lead, TPH, and low concentrations of volatiles were detected in all soil samples at Site 20. The TPH concentration was especially high in 20-SS3 (38,100,000 ppb), 20-SS4 (2,860,000) and 20-SS2 (600,000 ppb). The total lead concentration in 20-SS3 (242,000 ppb) was considerably higher than in the other soil samples. PAHs were detected in 20-SS1 only. The three PAH compounds detected in 20-SS1 were naphthalene (1,800 ppb), 2-methylnaphthalene (1,000 ppb), and 1-methylnaphthalene (800 ppb).

Low concentrations of six volatile organic compounds were detected at Site 20. Most of these compounds are associated with fuels or lubricants. The highest VOC was xylene, which was detected in 20-SS1 (450 ppb), 20-SS2 (10 ppb), and 20-SS4 (22 ppb). Ethylbenzene was detected at low concentrations in 20-SS1 and 20-SS4 and toluene was detected at low levels in 20-SS2 and 20-SS4. Carbon disulfide, trichlorofluoromethane, and 2-butanone also were detected at low concentrations in Site 20 soils.

Health and Environmental Assessment

Contaminants detected in the soils at Site 20 are compared against potential applicable federal and Virginia standards in Table 4-11-2. No contaminant concentrations at Site 20 exceeded either the established health-based criteria for systemic toxicants or the proposed RCRA action levels (EPA, 1990).

Although there are no federal criteria for total petroleum hydrocarbons in soil, the state of Virginia guidelines set a limit for TPH concentrations of 100,000 ppb. The TPH concentrations in 20-SS1 (600,000 ppb), 20-SS3 (38,100,000 ppb), and 20-SS4 (2,860,000 ppb) exceeded the Virginia guidelines.

The ecological assessment revealed that the inorganic concentrations detected in soil are well below background concentrations of elements in the eastern United States (Shacklette and Boerngen, 1984), with the exception of lead, which was 242,000 ppb in 20-SS3 versus a background of 14,000 ppb.

Fate and Transport

Groundwater transport and soil erosion are the potential transport mechanisms at Site 20. The land is flat so soil erosion is expected to be minimal. It is unclear to what depth the contamination extends. Contamination is higher from 0.5 to 1.0 foot than from 2.0 to 3.0 feet and may decrease more with depth. Navy sampling along the strip of grass did not indicate contamination below 2.5 feet (Hylton, 1993). The depth to water in most of the eastern part of the base is 8 to 10 feet. Infiltration through the unsaturated zone could

Table 4-11-1
ORGANIC COMPOUNDS AND LEAD IN SOILS AT SITE 20
January - February 1993
(All data in $\mu g/kg$)

Analyte	Detection Limit	20-SS1 0.5-1.0 ft		20-SS2[a] 2.0-3.0 ft	20—SS3[a] 0.5-1.0 ft	20—SS4[c] 2.0-3.0 ft
		Initial	Duplicate			
TPH	900	600,000	661,000	4,000	38,100,000	2,860,000
Total Lead	1,600	11,000[n+]	NA	13,400[n+]	242,000[n+]	4,600[n]
Polynuclear Aromatics						
Naphthalene	50	1,800	1,600	*	*	*
2-Methylnaphthalene	50	1,000[j]	940[j]	*	*	*
1-Methylnaphthalene	50	800[j]	600[j]	*	*	*
Volatile Organic Compounds						
Methylene Chloride	5	35[b]	38[b]	20[b]	17[b]	19[b]
Acetone	10	94	62	87	7[j]	40[b]
Carbon Disulfide	5	*	*	*	4[j]	3[j]
Trichlorofluoromethane	5	*	*	*	1[j]	*
Toluene	5	*	*	10	*	9
Ethylbenzene	5	42	17[j]	*	*	7
Xylene (Total)	5	450	130	10	*	22
2-Butanone (MEK)	10	*	*	27	*	*

Notes:
All volatile organic and polynuclear aromatic compounds not listed above were analyzed for but were not detected in any samples.
[a]The sample VOC data were qualified as estimated during the data validation process because the samples were analyzed outside the holding time limit.
b=Compound is found blank as well as sample.
[c]The sample VOC data were qualified as estimated during the data validation process because the surrogate recovery was low.
j=Indicates an estimated value.
*=The compound was below the detection limit.
+=Duplicate analysis not within control units.
n=Spiked sample recovery not within control units.
NA=Not Analyzed.
QC Sampling=20-SS30 is a duplicate of 20-SS1.

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T... -11-2
CONSTITUENTS DETECTED IN THE SOILS AT SITE 20 COMPARED AGAINST POTENTIALLY APPLICABLE FEDERAL AND STATE STANDARDS
January 1993

Compound	Location Detected	Concentration (ppb)	Concentrations in (μg/kg) Health-Based Criteria for Carcinogens	Health-Based Criteria for Systemic Toxicants	Proposed RCRA Action Level	Virginia Soil Guidelines	Eastern United States Mean Soil Concentration
TPH	20-SS1 20-SS2 20-SS3 20-SS4	600,000 4,000 38,100,000 2,860,000	NS	NS	NS	100,000	NA
Total Lead	20-SS1 20-SS2 20-SS3 20-SS4	11,000 13,400 242,000 4,600	NS	NS	NS	NS	14,000
PAHs Naphthalene 2-Methylnaphthalene 1-Methylnaphthalene	20-SS1	1,800 1,000 800	NS	NS	NS	NS	NA
Carbon Disulfide	20-SS3 20-SS4	4[j] 3[j]	NS	8,000	8,000,000	NS	NA
Trichlorofluoromethane	20-SS3	1[j]	NS	NS	20,000,000	NS	NA
Toluene	20-SS2 20-SS4	10 9	NS	20,000	20,000,000	NS	NA
Ethylbenzene	20-SS1 20-SS4	42 7	NS	8,000	8,000,000	NS	NA
Xylene	20-SS1 20-SS2 20-SS4	450 10 22	NS	200,000	200,000,000	NS	NA
2-Butanone	20-SS2	27	NS	4,000	4,000,000	NS	NA

Notes:
NS = No standard
The health-based criteria for carcinogens and systemic toxicants were taken from the *RFI Guidance Document*, EPA 530/SW-89-031, dated May 1989.
The proposed action levels were extracted from the *Federal Register*, Vol. 55, No. 145, dated July 27, 1990.
j = Indicates an estimated value.
NA = Not applicable to organics.

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transport some petroleum-related constituents down to the water table. Although there is no site-specific data on the localized groundwater system, groundwater generally flows southeast in the eastern half of the base where it is not otherwise controlled by ditches.

Recommendations

Because the soil near the shed where 20-SS3 and 20-SS4 were collected is clearly contaminated with waste oil, the soil in this area should be sampled to determine the extent of TPH contamination. Following additional characterization, soils should be excavated until TPH concentrations meet the Virginia standard of 100,000 ppb. Some amount of soil should also be excavated on the northwest end of the grass strip near 20-SS1 after a review of past excavation activities to avoid removing soil unnecessarily. The groundwater at this site should be sampled also.

Site 21—Transformer Storage Yard

Site Location and History

Site 21 is in the southwest corner of the Public Works Transportation Yard, approximately 400 feet southeast of Building 830. Transformers were stored in two gravel areas between the sand loaders and the yard's chain-linked fence (see Figure 4-12-1). Old electrical transformers (3.75 kW), which were known to contain PCBs, were stored on pallets over bare ground at this site until they could be disposed (RGH, 1984). The Public Works Transportation Yard has been in use since the early 1950s; however, it is unclear how long this area has been used for transformer storage (RGH, 1984). Transformers have been stored in the yard since at least 1982 when a transformer leaked a significant quantity of transformer oils, and the Navy hired a contractor to clean up the spill (RGH, 1984). Two transformers without release controls were seen leaking oil onto the ground during the VSI (RFA, 1988). Vegetation behind and down the slope from the transformers appeared to be dead (RFA, 1988).

Past Investigations and RFI Site Activities

Site 21 was reviewed during the RFA; however, there has been no previous environmental sampling at this site. The visual site inspection indicated that electrical oil from old transformers was leaking onto the ground, and the vegetation down the slope from the storage yard appeared to be dead.

The purpose of the RFI activities at Site 21 was to characterize the soils at the two areas used to store old transformers to determine if the oil releases contaminated the soils with PCBs.

CH2M HILL field personnel collected 10 soil samples from 0.5 to 1.0 foot in two locations where the transformers were stored. Figure 4-12-1 shows the soil sampling locations. Six soil samples (21-SS1 through 21-SS6) were collected in a gravel area adjacent to the sand loader. The remaining four soil samples (21-SS7 through 21-SS10) were collected along the fence line. The sampling focused on areas with staining and stressed vegetation. All samples were analyzed for PCBs. Samples 21-SS1 and 21-SS6 also were analyzed for TPH.

Environmental Setting

The study area consists of a large asphalt parking lot, a mowed lawn perimeter to the southeast and a part of the adjacent forest. The site encompasses approximately 10.5 acres. The asphalt parking area and storage yard and the adjacent lawn and forest are flat. The underlying soils in the area are a silty loam and poorly drained. A small recreational picnic area exists immediately east of the fence that surrounds the storage

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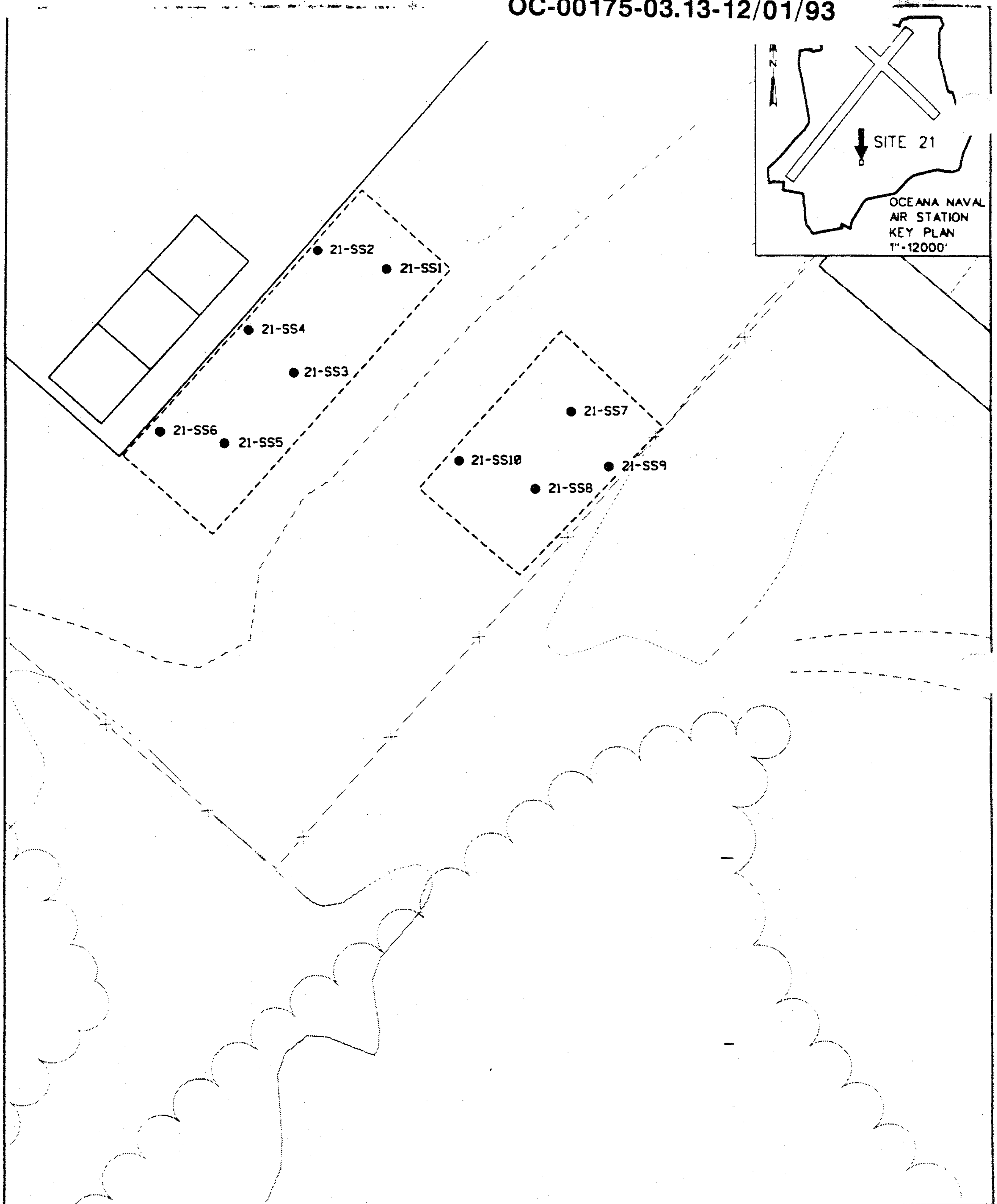

LEGEND

● SOIL SAMPLING LOCATION

TRANSFORMER STORAGE AREAS

Figure 4-12-1
RFI SAMPLING LOCATIONS
AT SITE 21
FEBRUARY 1993

CH2M HILL

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yard. This area has a few trees and a maintained lawn. Beyond the forest to the southeast is the golf course. Figure 4-8-3 in the Site 16 section is an ecological map of Sites 16, 21, 23, and 24. The sites are shown together because of their proximity.

Ecology

Drainage from the storage yard generally flows southeast. In the southeastern corner of the lot, an exposed storm sewer pipe extends from the asphalt, under the fence, and underground into the lawn perimeter. Significant erosion is taking place around the pipe near the corner of the fence. Uncontrolled surface flow apparently travels off the asphalt and is eroding the area around the pipe. A manhole cover was observed just inside the forested area southeast of the pipe. A series of small ditches were observed in the forested area. No water was in the ditches during the field survey. These ditches lead southwest toward the golf course and intersect a larger ditch, which flows southwest.

The study area may contain small patches of forested wetlands; however, none were observed in the immediate area during the assessment.

The forest vegetation is dominated by sweetgum, tulip poplar, and loblolly pipe. The understory consists of Japanese honeysuckle, greenbriar, and giant cane. Because it is maintained, the picnic area had no understudy. Loblolly pine dominated this area.

A mourning dove was observed roosting in a pine in the picnic area. Crows, turkey vultures, and starlings were the only other species observed in the vicinity. Large numbers of white-tailed deer inhabit the area as evidenced by the deer trails, tracks, and scat that were frequently observed in the forested area near Site 21.

Geologic and Hydrogeologic Characteristics

Shallow soil samples from 0.5 to 1.0 foot provide the only information on the geology at this site. The shallow soils observed during sampling were silts and sandy silts. The depth to the groundwater and the groundwater flow direction are not known.

Contamination and Extent

The analytical results are presented in Table 4-12-1. PCBs were not detected in any Site 21 soil samples. Table 4-12-1 indicates the range of detection limits for the various PCB compounds in each sample. With the exception of 21-SS1, the detection limits were 22 to 92 ppb for the various Aroclors. The detection limits for 21-SS1 probably were higher because of soil volume or moisture content. However, both of the soils analyzed for TPH contained petroleum hydrocarbons. The TPH concentrations were 9,100 ppb in 21-SS1, and 242,000 ppb in 21-SS6. The soil samples were taken from areas of soil staining, where possible.

Table 4-12-1
ORGANIC COMPOUNDS IN SOILS AT SITE 21
February 1993
(All data in μg/kg)

Analyte	21-SS1	21-SS2	21-SS3	21-SS4	21-SS5	21-SS6	21-SS7		21-SS8	21-SS9	21-SS10
							Initial	Duplicate			
PCB Compounds	* (<120-460)	* (<23-92)	* (<23-92)	* (<22-88)	* (<22-88)	* (<23-89)	* (<21-84)	* (<22-86)	* (<23-90)	* (<22-88)	* (<23-89)
TPH[a]	9,100	NA	NA	NA	NA	242,000	NA	NA	NA	NA	NA

Notes:
All PCB compounds on the Method 8080 analysis list that are not listed were analyzed but were not detected in any sample.
All samples were collected from a depth of 6 inches to 1 foot.
*The compound was analyzed but not detected. Parentheses indicate range of detection limits for various Aroclor compounds.
NA = Not analyzed
TPH = Total petroleum hydrocarbons
[a]The detection limit for TPH is 2,200 μg/kg.

WDCR704/013.51

OC-00175-03.13-12/01/93

Health and Environmental Assessment

Established health-based criteria nor proposed action levels for TPH in soil do not exist; however, there is a Commonwealth of Virginia guidance limit of 100,000 ppb. The TPH concentration in 21-SS6 (242,000 ppb) exceeds this limit. The RBCs for PCBs calculated by toxicologists at EPA Region III are 83 ppb for residential soil and 370 ppb for soil in commercial/industrial areas. With the exception of two Aroclors in 21-SS1, all detection limits were below the commercial/industrial RBC.

Fate and Transport

Soil erosion is the most important potential transport mechanism at this site. Most oil constituents and PCBs have a strong tendency to sorb to soil particles and are not highly mobile in water. PCBs were not found at this site and it is unlikely that they have been transported offsite by soil erosion because of the flat topography and the gravel ground cover. Because the water table in most of the eastern half of the station is approximately 8 to 10 feet from the surface, groundwater transport is a potential transport mechanism; however, TPH concentrations at the surface are generally low and, therefore, are not a substantial source.

Recommendations

The 10 soil samples collected during the RFI show that the shallow soils are not contaminated with PCBs. Because PCBs were the principle contaminants of concern and TPH contamination is extremely limited, no additional RFI or CMS activities are recommended.

Site 22—Construction Debris Landfill

Site Location and History

Site 22 is approximately 600 to 1,000 feet west of Oceana Boulevard and 1,500 feet north of the VACAPES complex. The landfill is an approximately 0.5-acre unlined facility that was in use at the time of the VSI. No release controls were observed (RFA, 1988). The age of the landfill is unknown, but it was first discovered in 1986 (RFA, 1988). The former permit status of this landfill is not known.

Although the Navy designated this landfill for construction debris, controls on the landfill's waste stream did not prevent the disposal of other types of waste. There have been no documented releases from this site.

Past Investigations and RFI Site Activities

There has been no previous environmental sampling at Site 22. The purpose of the RFI activities at the Construction Debris Landfill was to characterize the groundwater at this site and to determine if there had been any impact on the nearby wetlands. RFI sampling locations are shown in Figure 4-13-1.

The field investigation consisted of (1) installing four shallow monitoring wells (22-MW1 through 22-MW4), (2) sampling the groundwater at the four wells, and (3) sampling sediments (22-SD1 and 22-SD2) and surface water (22-SW1 and 22-SW2) in the stream adjacent to the site. The surface water and sediment samples were collected at one upstream (22-SD2 and 22-SW2) and one downstream location (22-SD1 and 22-SW1). The four monitoring wells were installed as indicated in Table 4-13-1.

Table 4-13-1
SITE 22 MONITORING WELL SUMMARY

Well Number	Date Installed	Ground Elevation	Total Depth	Screened Interval
22-MW1	12/15/92	16.0	20	9.5 - 19.5
22-MW2	12/17/92	15.6	23	13 - 23
22-MW3	12/16/92	19.2	28	18 - 28
22-MW4	12/17/92	16.6	23	13 - 23

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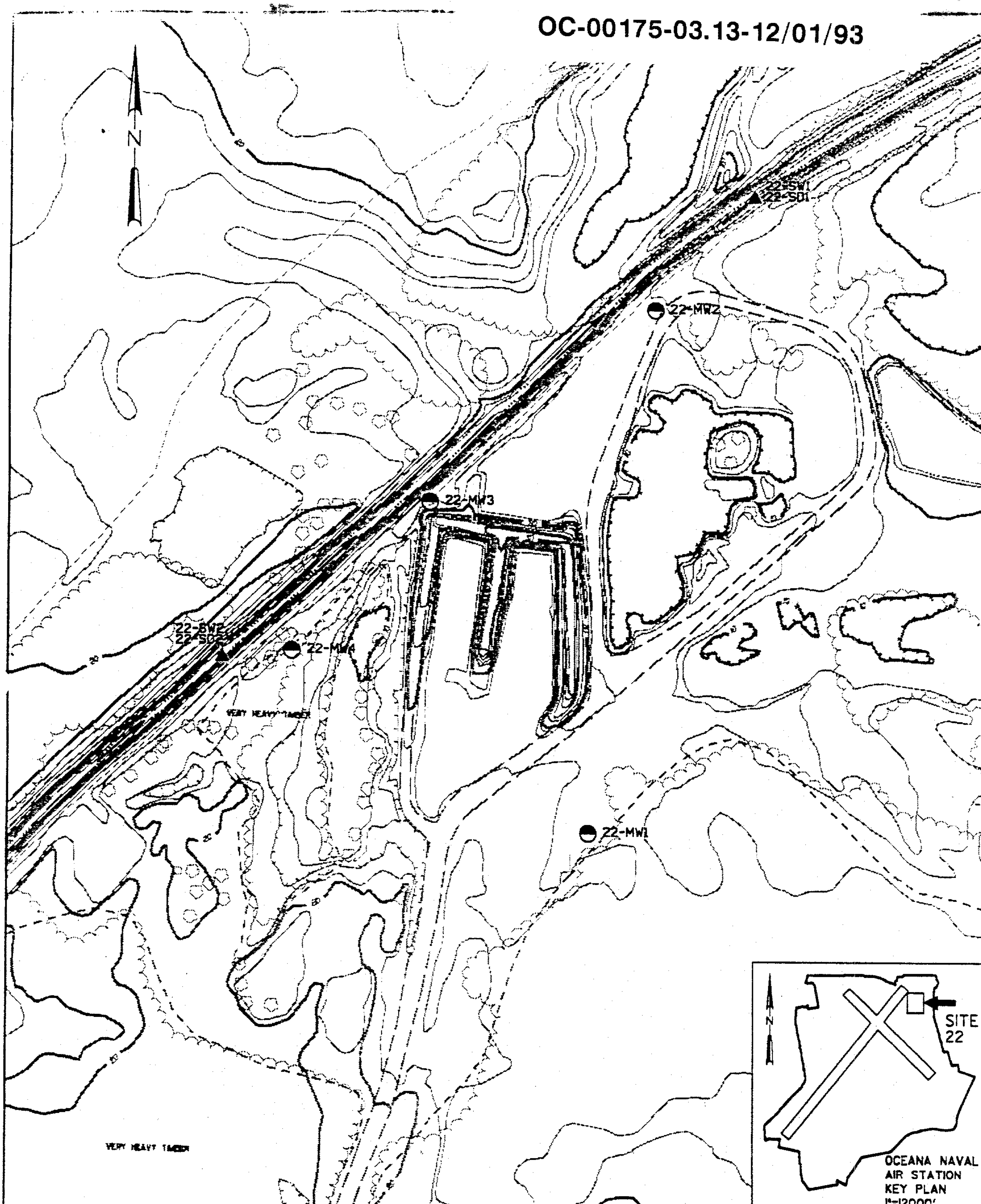

LEGEND

- SHALLOW MONITORING WELL
- SEDIMENT & SURFACE WATER SAMPLING LOCATIONS
- DIRECTION OF SURFACE WATER FLOW

Figure 4-13-1
RFI SAMPLING LOCATIONS
AT SITE 22
JANUARY 1993

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Because there was no previous sampling at this site, monitoring well 22-MW2 was analyzed for Appendix IX constituents. All other groundwater samples were analyzed for VOCs, semivolatiles, pesticide/PCBs, and total and dissolved metals. Sediment and surface water samples were analyzed for VOCs, pesticide/PCBs, and total metals.

Environmental Setting

The borders of the study area are Oceana Boulevard to the east, the ditch to the northwest, and the access road to the southwest. The site includes the two ponds and adjacent wetlands immediately south of the access road terminus and the area around the debris pile that occurs in the center of the site. The area encompasses approximately 33 acres.

This site has highly disturbed sandy soils. The terrain at road level is flat, but there are substantial man made berms, depressions, and debris piles at the site. The deep depressional area in the main terminal loop of the road contains disturbed clayey soils, and appears stressed because little vegetation is growing there. Vegetation appears stunted and nutrient depleted. Furniture, automobile parts, wood, and dirt make up most of the visible debris in the area. Two borrow ponds are in the study area. Several temporarily flooded depressions occur in the forested area southeast of the study area. The ponds are surrounded by sand, some of which is excavated regularly.

Ecology

Surface Water Resources. Figure 4-13-2 is an ecological map of Site 22. Two sand pit ponds occur on the site. These ponds are generally less than 6 feet deep (Hostetter, 1993). Water quality appeared good in the ponds as evidenced by the clarity of the water and the presence of abundant fish. A ditch runs along the northern boundary of the study area. This ditch flows northeast and is not influenced tidally. The water in the ditch was clear with patches of brown flocculated material caused by iron. Bottom sediments in the ditch were sandy. The water depth was approximately 6 inches. The forested swamp, west of the access road, was flooded at the time of the study. Water color in the swamp was dark, probably because of tannins from the surrounding trees. This area did not appear stressed at the time of study.

Wetlands. A large depressional forested swamp wetland occurs along the west side of the access road. This wetland was flooded to an unknown depth at the time of the study. The wetland is dominated by black willow. Several smaller ponded wetlands occur in the forested area east of the access road near the fence line. These wetlands appeared to temporarily flood, depending on seasonal conditions. The northeast corner of the site near the fence line at Oceana Boulevard contains a forested wetland system that was flooded at the time of the study (see Figure 4-13-2). This wetland area was dominated by pine and appears to be flooded year-round based on field indicators. Fringing emergent/shrub wetlands occur around portions of the two large ponds on site.

Figure 4-13-2
ECOLOGICAL MAP
FOR SITE 22
NAS OCEANA

CH2M HILL

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8-Apr-1993

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Vegetation. The soil near the ponds is very sandy. The plant community in this area is dominated by scrubby vegetation adapted to living in sandy, nutrient poor soils, including loblolly pine, glasswort species, grasses, waxmyrtle, and long-leaf pine. The forested areas are dominated by loblolly pine with giant cane in the understory. Giant cane also appears in areas of previous disturbance at the edge of forested areas. Several depressions, ditches, and small ponded areas have a variety of wetland vegetation, including; soft rush, sedges, black willow, purslane, and goldenrod. The deep depressional area at the access road turn around has very clayey, compact soils. The vegetation is indicative of disturbed, nutrient poor soils. The vegetation in the area includes path rush, bluestem, and stunted specimens of waxmyrtle, pine, and several weedy species.

Wildlife. The area around Site 22 provides unique and valuable habitat for a variety of wildlife and aquatic species. Several bird species, or their signs, were observed in the area, including great blue heron, mallard ducks, osprey, red-tail hawk. No mammals were observed in the area, however there are signs that fox, deer, raccoon, rodents, and possibly opossum occur in the area. Suitable habitat exists for a variety of wildlife because of the proximity to water and cover. Aquatic species observed during the study included bluegill, mudminnows, and largemouth bass.

Geologic and Hydrogeologic Characteristics

Shallow boreholes drilled at this site during the RFI indicate that the near-surface geology consists of a 5- to 10-foot-thick layer of sandy silts, and clay that is underlain by a 12- to 17-foot layer of clean sands with fine to coarse grains. These two units are part of the Columbia Group sediments described in Chapter 2. The monitoring wells at this site are screened in the clean sand layer.

Water-level measurements collected in January 1993 are listed in Table 4-13-2. Figure 4-13-3 illustrates the equipotential contour lines in the clean Columbia Group aquifer. The data show groundwater flows north or northwest towards the drainage ditch.

Table 4-13-2
SITE 22 WATER-LEVEL DATA
January 1993

Well	Depth to Water (Feet Below Survey Datum)	Water-Level Elevations (Feet Above Mean Sea Level)
22-MW1	6.58	12.03
22-MW2	9.98	8.10
22-MW3	12.10	9.08
22-MW4	8.56	10.21

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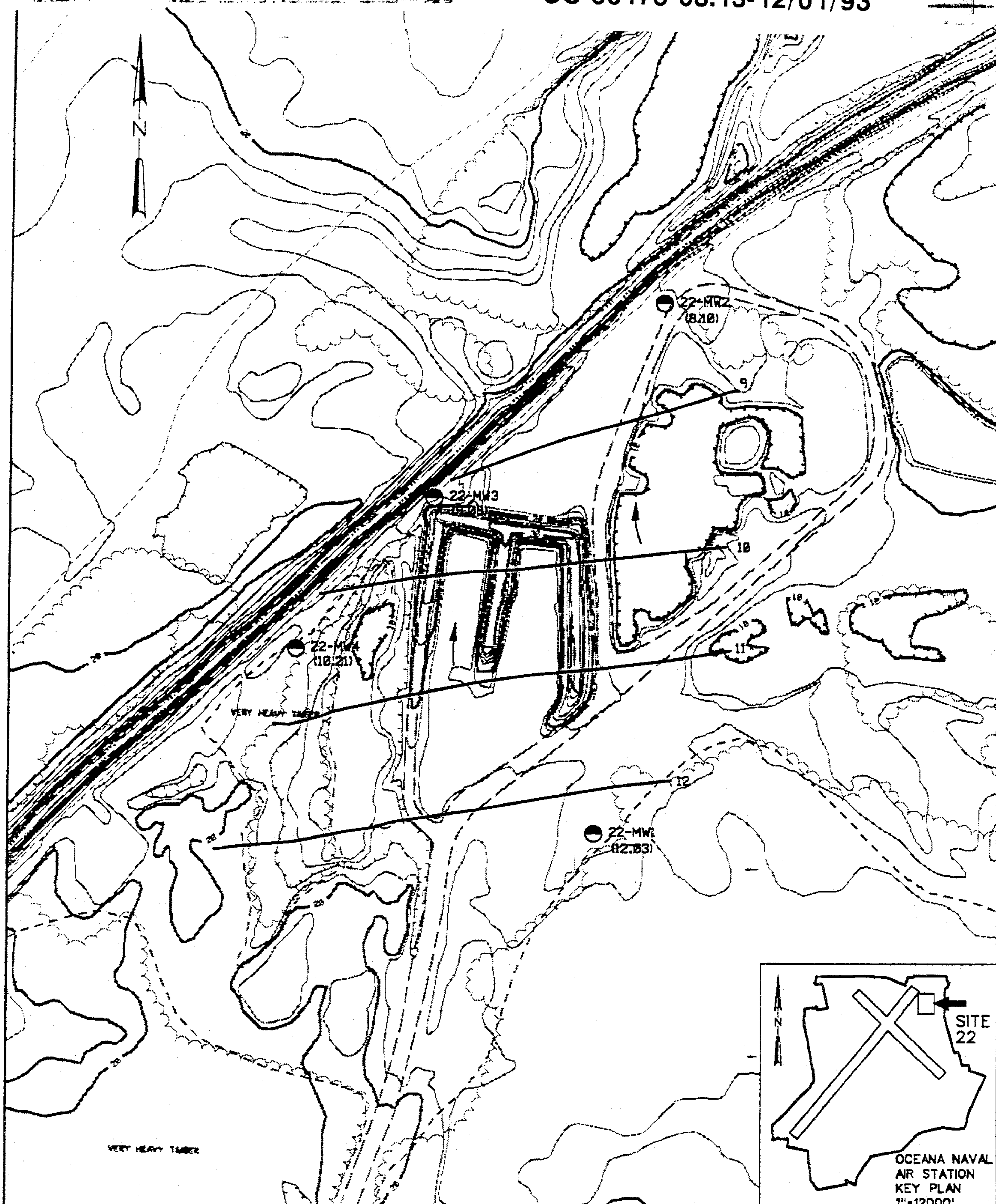

LEGEND

- SHALLOW MONITORING WELL
- ( ) WATER LEVEL ELEVATION, FEET
- DIRECTION OF GROUNDWATER FLOW

0 100 200 300
SCALE IN FEET

Figure 4-13-3
WATER TABLE ELEVATIONS AND EQUIPOTENTIAL CONTOURS AT SITE 22
JANUARY 26, 1993

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Contamination and Extent

The Site 22 analytical results for the three media analyzed: groundwater, surface water, and sediment, are listed in Tables 4-13-3 through 4-13-6. Groundwater results indicate that no organic constituents were detected in the wells at Site 22 except for four common laboratory contaminants that were found at concentrations of less than 10 ppb. All other organic analyses conducted on groundwater samples from Site 22, including pesticide/PCBs, Appendix IX organophosphorus pesticides, Appendix IX herbicides, and Appendix IX dioxins/furans, were not detected.

The results of groundwater analyses for inorganic metals are presented in Table 4-13-4. Metals that were detected in some wells include silver, arsenic, beryllium, cobalt, copper, mercury, zinc, and cyanide. All concentrations were low and were below MCLs. The metals that were detected at low levels in the total metals samples were absent in the corresponding dissolved metals samples.

The organic and inorganic compounds detected in sediments and surface water are listed in Tables 4-13-5 and 4-13-6, respectively. The duplicate of 22-SD1 contained low concentrations of benzene (3 ppb), toluene (3 ppb), ethylbenzene (11 ppb), and xylene (49 ppb). The initial sample did not contain any BTEX compounds.

The four pesticide compounds detected at very low concentrations in the sediment at Site 22 did not exceed NOAA guidelines. 4,4'-DDE and 4,4'-DDT were detected in both samples, whereas dieldrin and 4,4'-DDD were detected in 22-SD1 only. No pesticide compounds were detected in the surface water samples taken from the same locations in the drainage ditch.

Inorganic analysis of the sediment and surface water at Site 22 detected no metal compounds above RCRA action levels for soils or MCLs for surface water. Common inorganics such as iron, aluminum, magnesium, and manganese were higher in the downstream sediment sample (22-SD1) than in the upstream sample (22-SD2). There was no significant difference between levels in the upstream and downstream surface water samples.

Health and Environmental Assessment

Constituents detected at Site 22 that exceeded potentially applicable human-health and ecological standards are listed in Table 4-13-7. No human-health-based standards or guidelines were exceeded. Antimony, thallium, beryllium, and cadmium were not detected above their respective detection limits of 16.4, 2.3, 0.26, and 2.8 ppb. With the exception of two samples with anomalous results in split factions, all mercury results in groundwater were below the detection limit of 0.07 ppb. Manganese concentrations in 22-MW2 through 22-MW4 exceeded the aesthetic-based MCL goal of 200 ppb.

Table 4-13-3
ORGANIC COMPOUNDS IN GROUNDWATER AT SITE 22
January 1993
(All data in $\mu g/l$)

Analyte	Detection Limit	22-MW1	22-MW2		22-MW3		22-MW4
			Initial	Duplicate	Initial	Duplicate	
Volatile Organic Compounds							
Methylene Chloride	5	3 BJ	3 BJ	2 BJ	3 BJ	NA	2 BJ
Acetone	10	6 J	6 J	6 J	5 J	NA	6 J
Semivolatile Organic Compounds							
Bis(2-Ethylhexyl)Phthalate	10	7 BJ	10 B	10 B	10 B	NA	10 B
Di-n-Butylphthalate	10	*	*	*	*	NA	2 J
Pesticide/PCB Compounds	0.02-2.0	*	*	*	*	*	*
Appendix IX Organophosphorous Pesticides	1-2	NA	*	*	NA	NA	NA
Appendix IX Herbicides	0.5-2.5	NA	*	*	NA	NA	NA
Appendix IX Dioxins/Furans	.000027-.00016	NA	*	*	NA	NA	NA

Notes:

All volatiles, semivolatiles, pesticide/PCBs, organophosphorous pesticides, and dioxin/furans compounds not listed in the table above were analyzed but were below the detection limit in all samples.
22-MW2 was analyzed for the Appendix IX compounds.
QC Sampling: 22-MW30 is a duplicate of 22-MW2. 22-MW31, which is a duplicate of 22-MW3, was submitted for pesticide/PCB analysis only.
B - The analyte is found in the laboratory blank as well as the sample. The sample concentration is less than 3 times the blank concentration.
J - The compound is present below the stated quantition limit. This is an estimated value.
*The compound or compounds were analyzed but were not detected.
NA - Not analyzed.

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Table 4-13-4
INORGANIC COMPOUNDS IN GROUNDWATER AT SITE 22
January 1993
(All data in $\mu g/l$)

Analyte	22-MW1		22-MW2				22-MW3		22-MW4	
			Initial		Duplicate					
	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved
Silver	<2.0	<2.0	2.5 B	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Aluminum	439	74.9 B	NA	NA	NA	36.3 B	122 B	31.5 B	752	<24.3
Arsenic	<0.68	<0.68	<0.68	<0.68	<0.68	2.0 B	<0.68	1.6 B	<0.68	<0.68
Barium	44.4 B	39.9	24.3 B	22.6 B	21.6 B	38.7 B	38 B	37.2 B	40.5 B	35.4 B
Beryllium	0.43 B	<0.26	<0.26	<0.26	<0.26	<0.26	<0.26	<0.26	<0.26	<0.26
Calcium	13,500	13,800	NA	NA	NA	14,400	14,500	15,100	13,800	13,700
Cadmium	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.
Cobalt	4.6 B	<2.6	3.0 B	<2.6	<2.6	<2.6	<2.6	<2.6	<2.6	<2.
Chromium	3.7	<2.8	3.0 B	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.
Copper	2.2 B	<1.2	5.3 B	<1.2	1.4 B	<1.2	<1.2	<1.2	1.4 B	<1.
Iron	615	102	NA	NA	NA	9,940	9,340	9,500	9,110	8,73
Mercury	<0.07	<0.07	<0.07	0.23	<0.07	<0.07	<0.07	<0.07	0.1 B	<0.
Potassium	3,420 B	2,880 B	NA	1,930 B	NA	2,560 B	1,600 B	2,060 B	1,910 B	3,230
Magnesium	3,920 B	3,900 B	NA	NA	NA	7,240	7,260	7,170	9,630	9,20
Manganese	52.3	51.2	NA	NA	NA	285	279	279	303	294
Sodium	14,300	14,000	NA	NA	NA	13,100	12,800	12,800	12,800	14,2
Nickel	<9.4	<9.4	<9.4	<9.4	<9.4	<9.4	<9.4	<9.4	<9.4	<9
Lead	<1.7	<1.7	<1.7	<1.7	2.7 B	<1.7	<1.7	<1.7	1.9 B	<1

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Table 4-13-4
INORGANIC COMPOUNDS IN GROUNDWATER AT SITE 22
January 1993
(All data in μg/l)

Analyte	22-MW1		22-MW2				22-MW3		22-MW4	
			Initial		Duplicate					
	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved
Antimony	< 16.4	< 16.4	< 16.4	< 16.4	< 16.4	< 16.4	< 16.4	< 16.4	< 16.4	< 16.4
Selenium	< 1.8	< 1.8	< 1.8	< 1.8	< 1.8	< 1.8	< 1.8	< 1.8	< 1.8	< 1.8
Thallium	< 2.3	< 2.3	< 2.3	< 2.3	< 2.3	< 2.3	< 2.3	< 2.3	< 2.3	< 2.3
Vanadium	< 2.6	< 2.6	< 2.6	NA	< 2.6	< 2.6	< 2.6	< 2.6	< 2.6	< 2.6
Zinc	< 9.0	11.3	< 9.4 B	9.4 B	12.7 B	13.1 B	< 9.0	< 9.0	< 9.0	15.1 B
Tin	NA	NA	< 12.7	< 12.7	< 12.7	NA	NA	NA	NA	NA
Cyanide	NA	NA	1.4 N	NA	1.4 N	NA	NA	NA	NA	NA
Sulfide	NA	NA	< 100	NA	< 100	NA	NA	NA	NA	NA

Notes:

All samples were analyzed for total and dissolved metals, except for 22-MW2 and its duplicate, which were analyzed for Appendix IX metals with cyanide/sulfide and Appendix IX dissolved metals.
QC Sampling: 22-MW30 is a duplicate of 22-MW2.
< - The constituent was not detected at this instrument detection limit.
B - The reported value obtained was less than the CDRL, but greater than or equal to the IDL.
N - Spiked sample recovery not within control limits.

Table 4-13-5
ORGANIC COMPOUNDS IN SEDIMENT AND SURFACE WATER AT SITE 22
January 1993
(All data in ppb)

Sediment (μg/kg)				
Analyte	Detection Limit	22-SD1[a]		22-SD2
		Initial	Duplicate	
Volatile Organic Compounds				
Methylene Chloride	6	11 B	10 J	9 B
Acetone	12	8 J	62	8 J
Benzene	6	*	3 J	*
Toluene	6	*	3 J	*
Ethylbenzene	6	*	11	*
Xylene (Total)	6	*	49	*
Pesticide/PCB Compounds				
Dieldrin	0.79	0.56 J	0.51 J	*
4,4'-DDE	0.79	1.6	1.9	0.68 J
4,4'-DDD	1.5	1.1 J	1.4 J	*
4,4'-DDT	1.5	1.1 J	1.7	0.68 J

Surface Water (μg/l)			
Analyte	Detection Limit	22-SW1	22-SW2
Volatile Organic Compounds			
Methylene Chloride	5	1 BJ	4 BJ
Acetone	10	5 J	5 J
Pesticide/PCB Compounds	0.02-2.0	*	*

Notes:

All volatile organic and pesticide/PCB compounds not listed in the table above were analyzed but were below the detection limit in all samples.
[a]The field duplicate VOC results were in poor correlation with the initial sample VOC results as determined by the data validation process. No qualification was performed.
B - The analyte is found in the blank as well as the sample.
J - An estimated value.
*The compound was analyzed, but below the detection limit.
QC Sampling: 22-SD11 is a duplicate of 22-SD1.

Table 4-13-6
INORGANIC COMPOUNDS IN SEDIMENT AND SURFACE WATER AT SITE 22
January 1993

Analyte	Sediment (μg/kg)		Surface Water (μg/l)	
	22-SD1	22-SD2	22-SW1	22-SW2
Aluminum	2,400,000	384,000	138 B	181 B
Antimony	<3,900 N	<4,000 N	<16.4	<16.4
Arsenic	1,800 B	640 B	1.1 B	<0.68
Barium	8,500 B	3,600 B	34 B	36.3 B
Beryllium	80 B	<60	<0.26	<0.26
Cadmium	<660	<670	<2.8	<2.8
Calcium	191,000 B	98,800 B	8,760	9,170
Chromium	6,200	1,300 B	<2.8	<2.8
Cobalt	750 B	<650	3.4 B	<2.6
Copper	1,800 BN+	<290 N+	<1.2	<1.2
Iron	3,000,000	714,000	1,250	1,070
Lead	3,500 N	5,500 N	1.7 B	<1.7
Magnesium	357,000 B	44,200 B	5,520	5,260
Manganese	12,400	1,500 B	102	73.9
Mercury	50 B	50 B	<0.07	<0.07
Nickel	<2,300	<2,300	<9.4	<9.4
Potassium	238,000 B	<228,000	1,300 B	1,920 B
Selenium	<440	<450	<1.8	<1.8
Silver	<470	<480	<2.0	<2.0
Sodium	241,000	244,000 B	9,200	8,970
Thallium	<550	<570	<2.3	<2.3
Vanadium	7,700 B	1,200 B	<2.6	<2.6
Zinc	6,800+	4,300 B+	15.9 B	14.1 B

Notes:

All samples were analyzed for total metals.
QC Sampling: 22-SD11 is a duplicate of 22-SD1.

B The reported value obtained was less than the CDRL, but greater than or equal to the IDL.
< The constituent was not detected at this IDL.
N Spiked sample recovery not within control limits.
+Duplicate analysis not within control limits.

Table 4-13-7
CONSTITUENTS DETECTED AT SITE 22
THAT EXCEEDED POTENTIALLY APPLICABLE CRITERIA
January 1993
(All data in ppb)

Compound	Location Detected	Concentration	Proposed RCRA Action Levels	Human-Health Criteria for the Ingestion of Water and Fish[a]	Fresh-Water-Quality Criteria for Aquatic Life	MCL Goal
Arsenic	22-SW1	1.1	50	0.0022	190	50
Iron	22-SW1 22-SW2	1,250 1,070	NS	300	1,000	NS*
Manganese	22-SW1 22-SW2 22-MW1 (dissolved, total) 22-MW2 (duplicate, dissolved) 22-MW3 22-MW4 (dissolved, total)	102 73.9 51.2, 52.3 285 279 294, 303	NS	50	NS	200*

Notes:

a = See Appendix A for discussion.
*The aesthetic-based secondary MCL for iron is 300 ppb. The secondary MCL for manganese is 50 ppb.
NS = No standard.

The maximum concentrations of potential ecological COCs detected in surface water at Site 22 were arsenic (1.1 ug/l), iron (1,250 ug/l), and manganese (102 ug/l). Mercury, nickel, and silver were not detected in surface water. There was a minimal difference between results upstream and downstream of the landfill, therefore constituents detected may not be caused by the landfill.

Because there are no inorganic standards for exposure of terrestrial organisms, human-health standards were applied to animals as a basis for comparison. See Appendix A for an explanation of the use of human-health standards for cases in which no ecological standards exist. The human-health values for exposure through ingestion of contaminated water and aquatic organisms are 0.0037 μg/l for beryllium, 0.0022 μg/l for arsenic, 50 μg/l for manganese, and 300 μg/l for iron (EPA, 1987). These values, as applied to the protection of terrestrial organisms, are assumed to be somewhat high, because of differences in biomass and ingestion rates. However, because the route of exposure and bioavailability are assumed to be the same in both cases, these criteria identify potential risk for effects to terrestrial organisms through ingestion of water and aquatic life. Iron was detected in the surface water samples in excess of its 300 ppb aquatic criterion. Aquatic life aluminum criteria are pH-dependent. pH was not measured at the time of surface water sampling. Arsenic, iron, and manganese are potential ecological COCs on the basis of this comparison. Refer to Appendix A for an explanation of potential ecological effects.

Fate and Transport

Because no contamination was found in groundwater at Site 22, groundwater transport is not a concern. Pesticides found at very low levels in sediment are primarily either DDT or its breakdown products, all of which are pesticides that have been banned since the 1970s. All are known to persist in the environment, so their presence is probably a product of slow releases from nearby land where they were applied. Site 22 is not likely to be a source of these pesticides.

Recommendations

Because significant contamination was not found at Site 22, no further investigation is recommended.

Site 23—Bowser, Building 830

Site Location and History

Site 23 is adjacent to Building 830, which has housed the Public Work's Transportation Division since 1954 (see Figure 4-14-1). The site has been the storage location of a bowser used to collect waste motor oil drained from the heavy and light equipment of the Public Works fleet. The waste oil drained into a 55-gallon drum, which had been cut in half, and then was pumped into the 500-gallon bowser outside Building 830 (RFA, 1988). Approximately 1,500 to 2,000 gallons of waste oil are generated each year (RFA, 1988). After the bowser was full, it was transferred to the Fuel Division Storage Yard for transfer to storage tanks (IAS, 1984). During the VSI, waste oil was visible on the shop floor surrounding the 55-gallon drum and heavy staining was seen on the ground below the waste oil bowser (RFA, 1988). Current practice is to pump waste oil into 55-gallon drums and transport the drums to the base hazardous waste lot, where they are transferred to the Defense Reutilization Management Office (DRMO) and then disposed or recycled appropriately (Hylton, 1993). The bowsers are no longer used and were not present at the time of RFI sampling activities.

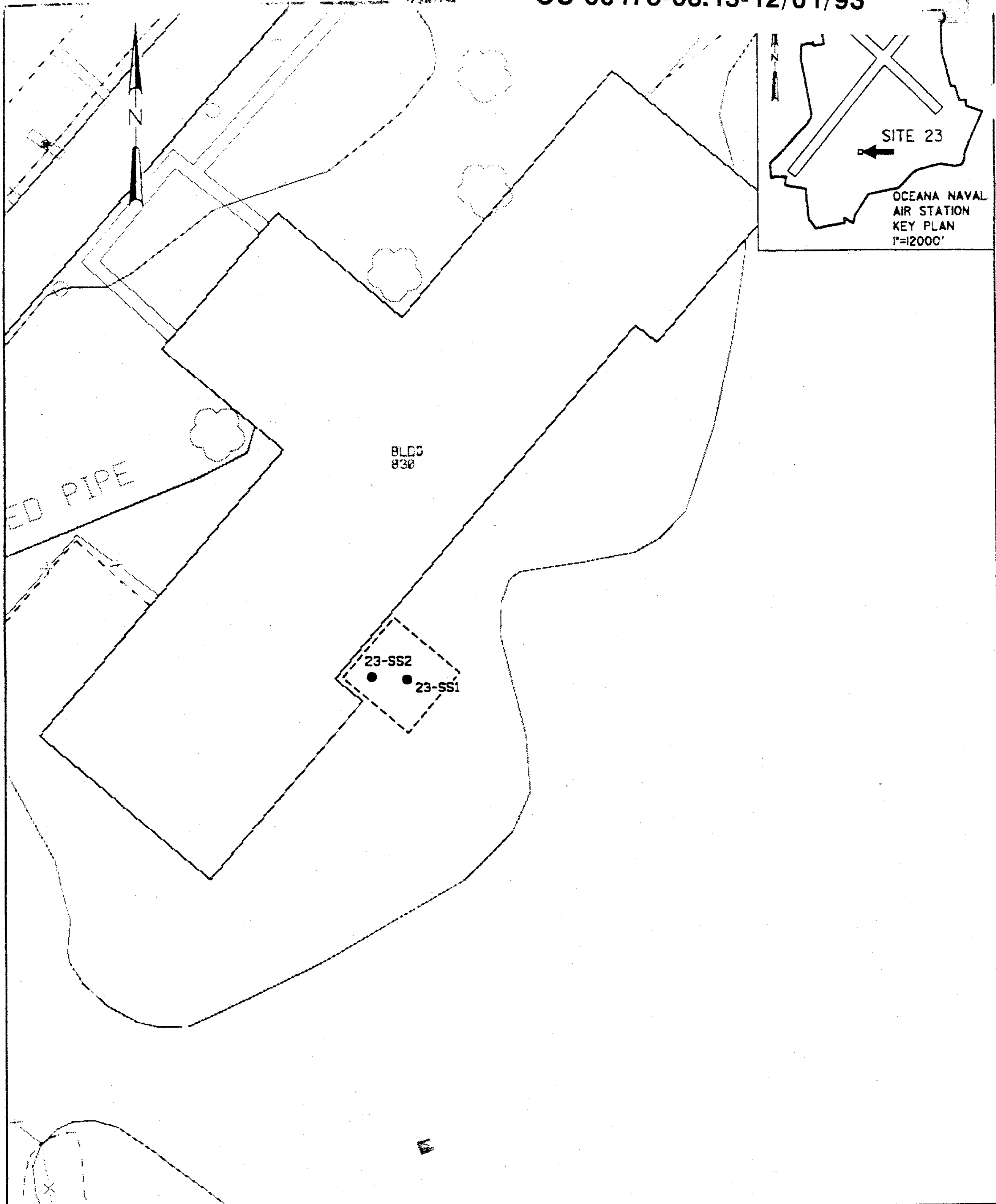
Past Investigations and RFI Site Activities

The site was not previously environmentally sampled. The purpose of the RFI site activities was to characterize the soil in the area where the bowser was parked. CH2M HILL field personnel collected two soil samples (23-SS1 and 23-SS2) from this area. Samples were collected with a hand auger from a depth of 0.5 to 1.0 foot below the bottom of the asphalt after jackhammering through the pavement. The samples were collected in a fine, clean sand that appeared to be fill material used in the construction of the Public Works Transportation Yard. The samples were analyzed for VOCs, PAHs, TPH, and total metals. Soil sampling locations are shown in Figure 4-14-1.

Environmental Setting

Site 23 is within a large flat asphalt parking lot adjacent to areas of scrub-shrub and forest. Southeast of the storage yard fence, near Site 21, is a picnic area with maintained lawn and several trees. Southwest of the storage yard is open ground and a road. The soil underlying the area is a silty loam that is poorly drained. Figure 4-8-3 is an ecological map of Sites 16, 21, 23, and 24. The ecology of these four sites is interconnected because of their proximity. Refer to the environmental setting section for Site 21 for additional details about the Site 23 environmental setting.

The geology of this site cannot be described precisely because no borehole logs exist. Two soil samples were collected beneath the asphalt parking lot at Building 830 during the RFI. The soil was a clean, poorly graded, coarse sand that appeared to be fill material used in the construction of the parking lot. No site-specific hydrogeologic data is available.



LEGEND

● SOIL SAMPLING LOCATION

APPROXIMATE BOUNDARY OF SWMU

0 25 50 75
SCALE IN FEET

Figure 4-14-1
RFI SAMPLING LOCATIONS
AT SITE 23
FEBRUARY 1993

CH2M HILL

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Contamination and Extent

The organic and inorganic results are presented in Tables 4-14-1 and 4-14-2. PAHs and VOCs were not detected in either sample. TPH concentrations of 63,800 ppb (23-SS1) and 2,100 ppb (23-SS2) were detected; however, they do not exceed the Virginia guidance level of 100,000 ppb.

Total metals analysis revealed low concentrations of several metals in the soil, including arsenic, barium, beryllium, chromium, cobalt, copper, selenium, vanadium, and zinc.

Health and Environmental Assessment

Antimony and beryllium exceeded potentially applicable human or ecological criteria. Antimony was found in soil at a maximum of 3,400 ppb, which is higher than background concentrations in the eastern United States (520 ppb). This does not necessarily indicate that antimony is an ecological threat (see Appendix A). Beryllium was present below the quantitative detection limit at 240 ppb. This concentration is above the health-based criteria for carcinogens of 143 ppb and the proposed RCRA action level of 200 ppb but is below the mean soil concentration in the eastern United States of 550 ppb (Shacklette and Boerngen, 1984). The concentration of arsenic in soil sample 23-SS1 (1,200 ppb) was above the residential carcinogenic RBC calculated by EPA toxicologists (Smith, 1993) but was below the commercial/industrial carcinogenic RBC and both noncarcinogenic RBCs. However, because the mean concentration in the eastern United States is 4,800 ppb, the concentration in 23-SS1 is probably not an indication of site contamination.

Fate and Transport

The asphalt parking lot overlying the contaminated soils eliminates the potential for soil erosion as a transport mechanism. In addition, the asphalt reduces the potential for precipitation to penetrate the shallow soils and leach down to the water table. Because of site conditions, the potential for migration of contamination by either soil or groundwater transport is low.

Recommendations

Because contaminant concentrations are low and Site 23 is covered with asphalt, which eliminates the principle soil exposure pathways, no future RFI or CMS action at this site is recommended.

Table 4-14-1
ORGANIC COMPOUNDS IN SOILS AT SITE 23
February 1993
(All data in μg/kg)

Analyte	23-SS1	23-SS2[a]
TPH	63,800	2,100
Polynuclear Aromatics (PAHs)	*	*
Volatile Compounds		
Methylene Chloride	4 bj	6 b
Acetone	10 j	9 j

Notes:
All polynuclear aromatics and volatile compounds not listed in the table above were analyzed but not detected in any samples.
*Compound analyzed but not detected.
[a]The sample VOC results were qualified as estimated during the data validation process because the sample was analyzed outside the holding time.
b=The analyte was found in the associated blank as well as the sample.
j=Estimated value. The compound was present below the stated quantitation limit.

Table 4-14-2
INORGANIC COMPOUNDS IN SOILS AT SITE 23
February 1993
(All data in μg/kg)

Analyte	23-SS1	23-SS2
Aluminum	4,030,000	1,260,000
Antimony	<3,400 n	<3,400 n
Arsenic	1,200 b	480 b
Barium	19,800 b	3,100 b
Beryllium	240 b	<50
Cadmium	<580	<570
Calcium	662,000 b	175,000 b
Chromium	2,700	1,800 b
Cobalt	1,400 b	<540
Copper	1,800 b	2,100 b
Iron	2,820,000	461,000
Lead	5,700 +	860 +
Magnesium	419,000 b	57,000 b
Manganese	58,800	2,800 b
Mercury	<30	<30
Nickel	<2,000	<1,900
Potassium	285,000 b	<191,000
Selenium	460 b	450 b
Silver	<420	<410
Sodium	141,000 b	137,000
Thallium	<490	<480
Vanadium	4,100 b	1,100 b
Zinc	16,000	4,400

Notes:
< The constituent was not detected at this instrument detection limit (IDL).
n=Spiked sample recovery not within control limits.
b=The reported value was less than CRDL, but greater than or equal to the IDL.
+=Duplicate analysis not within control limits.

Site 24—Bowser, Building 840

Site Location and History

Site 24 is a bowser near Building 840 (see Figure 4-15-1). The Naval Construction Battalion (SEABEEs) has been based in Building 840 since 1972. The SEABEEs are involved in construction at Oceana NAS and other local naval installations (RFA, 1988). Waste solvents and oils generated at the equipment maintenance garage in Building 840 were hand-carried and poured into the bowser, which was typically in the southernmost corner of the SEABEE compound (RFA, 1988). The bowser then was transported to the tank farm for disposal (RFA, 1988). During the VSI, heavy staining of the ground was observed in the area surrounding the waste oil bowser at Building 840 (RFA, 1988). Current practice is to dispose of waste oil in drums that are transported to the base hazardous waste lot, where they are transferred to the DRMO and disposed or recycled appropriately. The bowsers are not used. During CH2M HILL's RFI sampling, the bowser was not present and Navy personnel on the site during the sampling had no knowledge of it.

Past Investigations and RFI Site Activities

Before the RFI site activities, there has been no environmental sampling performed at this site. The RFA found that the practice of collecting waste solvents and oils and disposing of them in the bowser had stained the nearby soil, so the site was identified for further study in the RFI.

The purpose of the RFI site activities was to characterize the soils in the area where the waste oil bowser was parked. The field investigation consisted of collecting two soil samples (24-SS1 and 24-SS2) within 25 feet of the southeast corner of a shed adjacent to the southwest fence. This location was specified by NAS Oceana personnel familiar with waste-handling practices. Samples were collected with a hand auger from a depth of 0.5 to 1.0 foot below the ground surface. Soil sampling locations are shown in Figure 4-15-1.

Environmental Setting

Site 24 consists of a fenced unpaved area surrounded by a perimeter of scrub-shrub, maintained lawn, and forest. The immediate site area is approximately half an acre but the surrounding forests comprise several acres. An ecological map of Sites 16, 21, 23, and 24 is presented in Figure 4-8-3 as part of the Site 16 section. The ecology of these four sites is interconnected so they are presented as a unit. Refer to the environmental setting section of Site 21 for more details about the environmental setting of Site 24.

The geology of this site cannot be determined precisely because no borehole logs exist. Two surficial soil samples were collected in an area undergoing construction at the time of sampling. The soils were lean sandy silts. No data are available on the hydrogeology of Site 24.

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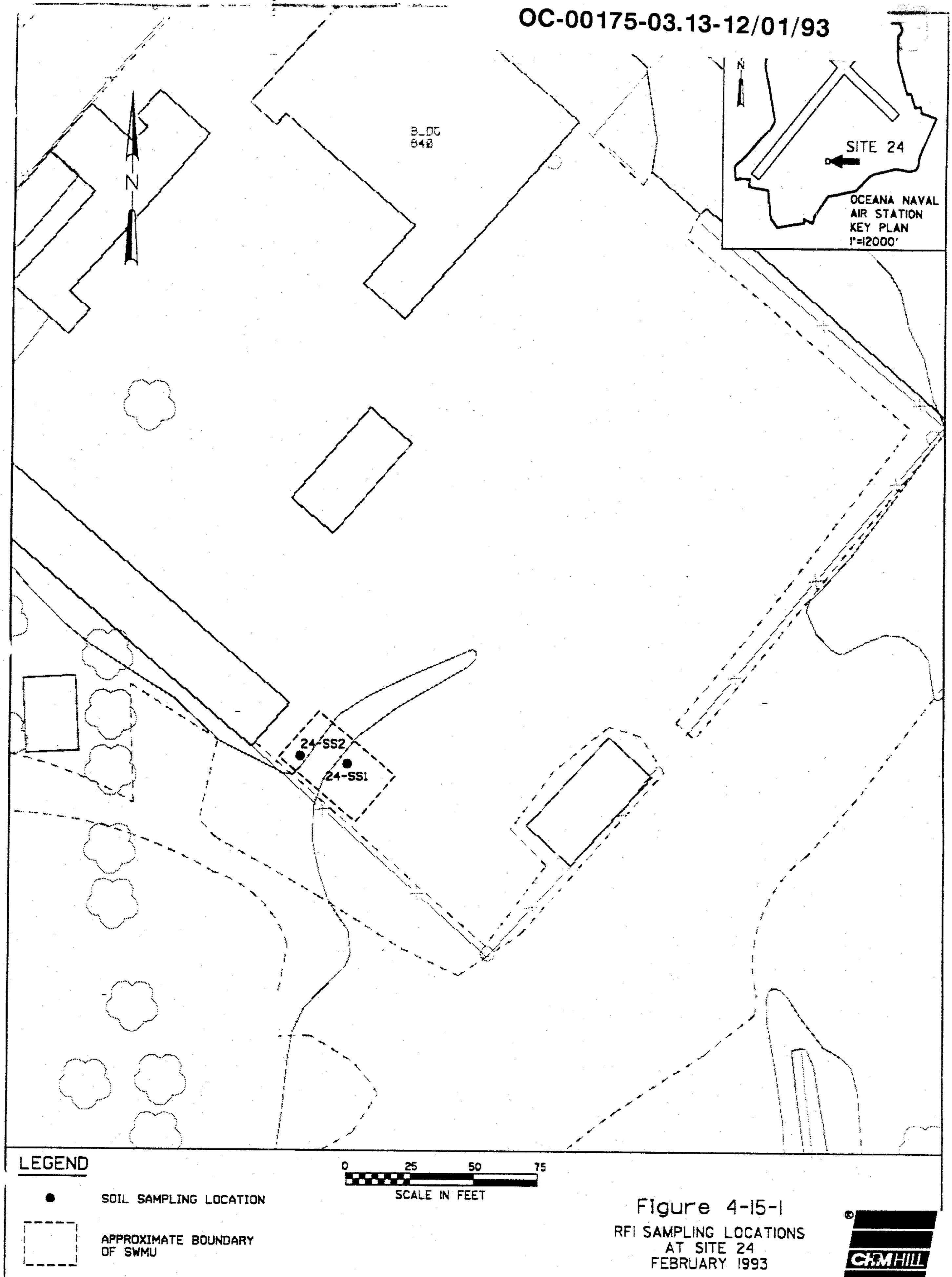

Figure 4-15-1
RFI SAMPLING LOCATIONS
AT SITE 24
FEBRUARY 1993

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Contamination and Extent

The analytical laboratory detected elevated TPH and volatile and PAH constituents in the two soil samples (24-SS1 and 24-SS2) submitted for analysis. The analytical results are presented in Tables 4-15-1 and 4-15-2. TPH concentrations were elevated above Virginia guidance levels in both samples. 24-SS1 contained 341,000 ppb and 24-SS2 contained 224,000 ppb versus the Virginia guidance of 100,000 ppb. Xylene and ethylbenzene were the most highly concentrated VOCs detected at Site 24. 24-SS2 contained the highest concentrations, 490 ppb and 110 ppb, respectively. All other VOC detections at Site 24 were either below the quantitative detection limit or are typical laboratory contaminants.

Six PAH compounds were detected at Site 24. Naphthalene, 2-methylnaphthalene, and 1-methylnaphthalene were detected in 24-SS2 in concentrations of 4,900 ppb, 3,300 ppb, and 3,700 ppb, respectively. The remaining three PAHs were detected in 24-SS1. They were pyrene at 320 ppb, chrysene at 1,100 ppb, and benzo(a)pyrene at 860 ppb. The pyrene concentration is an estimated value because its concentration was below the quantitative detection limit.

The inorganic analyses performed on the Site 24 soils detected metals that are naturally abundant in soils and several heavy metals at low concentrations, including arsenic, beryllium, chromium, vanadium, mercury, and nickel.

Health and Environmental Assessment

Table 4-15-3 lists compounds detected at Site 24 that exceeded potentially applicable health-based standards. No site constituents were above ecological limits. The benzo(a)pyrene concentration of 860 ppb in 24-SS1 exceeded the health-based criterion for carcinogens of 60.9 ppb. The beryllium concentration in 24-SS2 (560 ppb) exceeded both the health-based criterion for carcinogens (143 ppb) and the proposed RCRA action level (200 ppb). However, as shown in Appendix A, this beryllium concentration is approximately equal to the mean background concentration in the eastern United States (Shacklette and Boerngen, 1984).

The concentrations of four metals were below health-based criteria but were above mean background concentrations for the eastern United States. The maximum detected concentrations of antimony (4,400 ppb versus a background of 520 ppb), lead (14,600 ppb versus 14,000), mercury (110 ppb versus 81 ppb), and selenium (1,000 ppb versus 300 ppb) were all above background. These background concentrations were used for screening and do not suggest that these metals pose an environmental threat. The concentrations of arsenic in the two samples (1,100 to 1,600 ppb) were below noncarcinogenic RBCs and the carcinogenic RBC for commercial/industrial areas but above the carcinogenic RBC for residential areas. However, the mean concentration in the eastern United States is estimated to be 4,800 ppb, so arsenic levels at Site 24 do not necessarily indicate contamination.

Table 4-15-1
ORGANIC COMPOUNDS IN SOILS AT SITE 24
February 1993
(All data in μg/kg)

Analyte	24-SS1	24-SS2
TPH	341,000	224,000
Volatile Compounds		
Methylene chloride	19 b	61 b
Acetone	68	260
2-Butanone	11 j	62 j
Xylene (total)	4 j	490
Ethylbenzene	*	110
Toluene	*	15 j
Polynuclear Aromatic Compounds		
Naphthalene	*	4,900
2-Methylnaphthalene	*	3,300
1-Methylnaphthalene	*	3,700
Pyrene	320 j	*
Chrysene	1,100	*
Benzo(a)pyrene	860	*

Notes:
All volatile and polynuclear aromatic compounds not listed in the table above were analyzed for but not detected in any samples.
(*) Compound analyzed but not detected
b The analyte is found in the associated blank as well as the sample.
j Indicates an estimated value.
TPH Total petroleum hydrocarbons.

Table 4-15-2
INORGANIC COMPOUNDS IN SOILS AT SITE 24
February 1993
(All data in mg/kg)

Analyte	24-SS1	24-SS2
Aluminum	2,110	14,700
Antimony	<3.6	<4.4
Arsenic	1.1 B	1.6 B
Barium	7.7 B	61.1
Beryllium	0.08 B	0.56 B
Cadmium	<0.60	<0.74
Calcium	370 B	1,110 B
Chromium	3.5	14.2
Cobalt	0.69 B	1.7 B
Copper	1.8 B	6.8
Iron	1,760	3,770
Lead	3.5	14.6
Magnesium	309 B	825 B
Manganese	14.3	29.3
Mercury	<0.04	0.11 B
Nickel	<2.1	2.9 B
Potassium	<204	512 B
Selenium	<0.40	1.0 B
Silver	<0.44	<0.53
Sodium	152 B	207 B
Thallium	<0.51	<0.62
Vanadium	4.7 B	16.5
Zinc	15.6	31.2

Notes:
< The constituent was not detected at this instrument detection limit (IDL).
B The reported value was less than the Contract Required Detection Limit, but greater than or equal to the IDL.

Table 4-15-3
CONSTITUENTS DETECTED IN SOILS AT SITE 24 THAT EXCEEDED POTENTIALLY APPLICABLE FEDERAL AND STATE STANDARDS
February 1993
(All data in ppb)

Compound	Location Detected	Concentration (ppb)	Health Based Criteria for Carcinogens	Health Based Criteria for Systemic Toxicants	Proposed RCRA Action Levels	Virginia Soil Guidance Limit	Eastern United States Mean Soil Concentration
Benzo(a)pyrene	24-SS1	860	60.9	NS	NS	NS	NA
Beryllium	24-SS2	560	143	400,000	200	NS	550
TPH	24-SS1 24-SS2	341,000 224,000	NS	NS	NS	100,000	NA

Notes:

Only the contaminants detected at Site 24 that exceeded their respective standards are presented in this table.
Health based criteria for carcinogens and for system toxicants were published in the RFI Guidance Document EPA 530/SW-89-031.
Proposed RCRA action limits were extracted from the Federal Register dated 27 July 1990.
Virginia soil guidance limit is not a regulation but rather a guideline used by the VWCB for the implementation of a corrective action.
NS - No Standard

WDCR708/019.51

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TPH was above Virginia guidelines in both soil samples. Although there are no regulatory limits for TPH, the Virginia Water Control Board has established a guidance limit of 100,000 ppb. The Control Board uses this guidance limit when deciding whether to enforce a corrective action (Jacobeen, 1993). No inorganics were above standards.

Fate and Transport

The main potential transport mechanism at Site 24 is soil erosion. Because the samples were collected from 0.5 to 1 foot and the soil surface is not covered with gravel or vegetation, contaminants could erode away slowly with surficial soils. Depending on the depth of contamination, downward infiltration followed by groundwater transport also could be an important transport mechanism. If the organic constituents are limited to the shallow soils, groundwater transport is not likely to be significant.

Recommendations

RFI sampling at this site should be continued to determine the depth of soil contamination by TPH, PAHs, and volatiles. Groundwater also should be sampled.

Site 25—Inert Landfill

Site Location and History

Site 25 north of Potters Road on 26 acres of land is a landfill filled primarily with construction debris and demolished concrete (see Figure 4-16-1). According to the RFA, the facility is unlined and was used as a borrow pit that supplied soil used in the construction of State Route 44. The pit was developed in a fine, sandy loam soil that has a moderately high hydraulic conductivity. Eventually, the pit filled with water and was used as a local dump. According to the ecological coordinator at the Oceana environmental office, the pit is not used for recreational fishing. Borrow areas east of the inert landfill have also filled with water. NAS Oceana purchased the land in 1979 and received a permit from the Virginia Department of Health on May 24, 1979, permitting the disposal of inert solid waste. Waste disposal, however, may have begun as early as 1978 (RFA, 1988). NAS Oceana currently disposes of inert demolition debris at this site; however, uncontrolled community waste disposal of unknown materials took place before NAS Oceana's purchase of the site.

During the VSI, direct releases to the surrounding soils were observed (RFA, 1988). On the north shore of the pit, construction debris and scrap metal were present (RFA, 1988). Personnel from the state of Virginia identified wood and waste paper products at this landfill in 1981 (RFA, 1988).

The landfill was being used as a disposal site for concrete rubble during the RFI fieldwork. Concrete from both the MATWING and FITWING aircraft parking areas was being removed and hauled to this landfill in large pieces. The concrete pile was approximately 30 feet above grade during the RFI. The Navy is considering having a contractor grind up all the concrete rubble into small pieces and haul the material off station.

Past Investigations and RFI Site Activities

There has been no previous environmental sampling at Site 25. Because the site was used by the public for unpermitted nuisance dumping of unknown solid wastes before it was purchased by the Navy, its inclusion in the RFI was recommended in the RFA.

The purpose of the RFI site activities was to characterize the surface water and sediment at the pond where solid wastes were disposed. CH2M HILL personnel collected two surface water samples (25-SW1 and 25-SW2) and three sediment samples (25-SD1 through 25-SD3). Two sediment samples (25-SD1 and 25-SD3) and a surface water sample (25-SW1) were collected in the pond whereas the samples from 25-SD2 and 25-SD3 were collected in the ditch. The surface-water and sediment sampling locations are shown in Figure 4-16-1.

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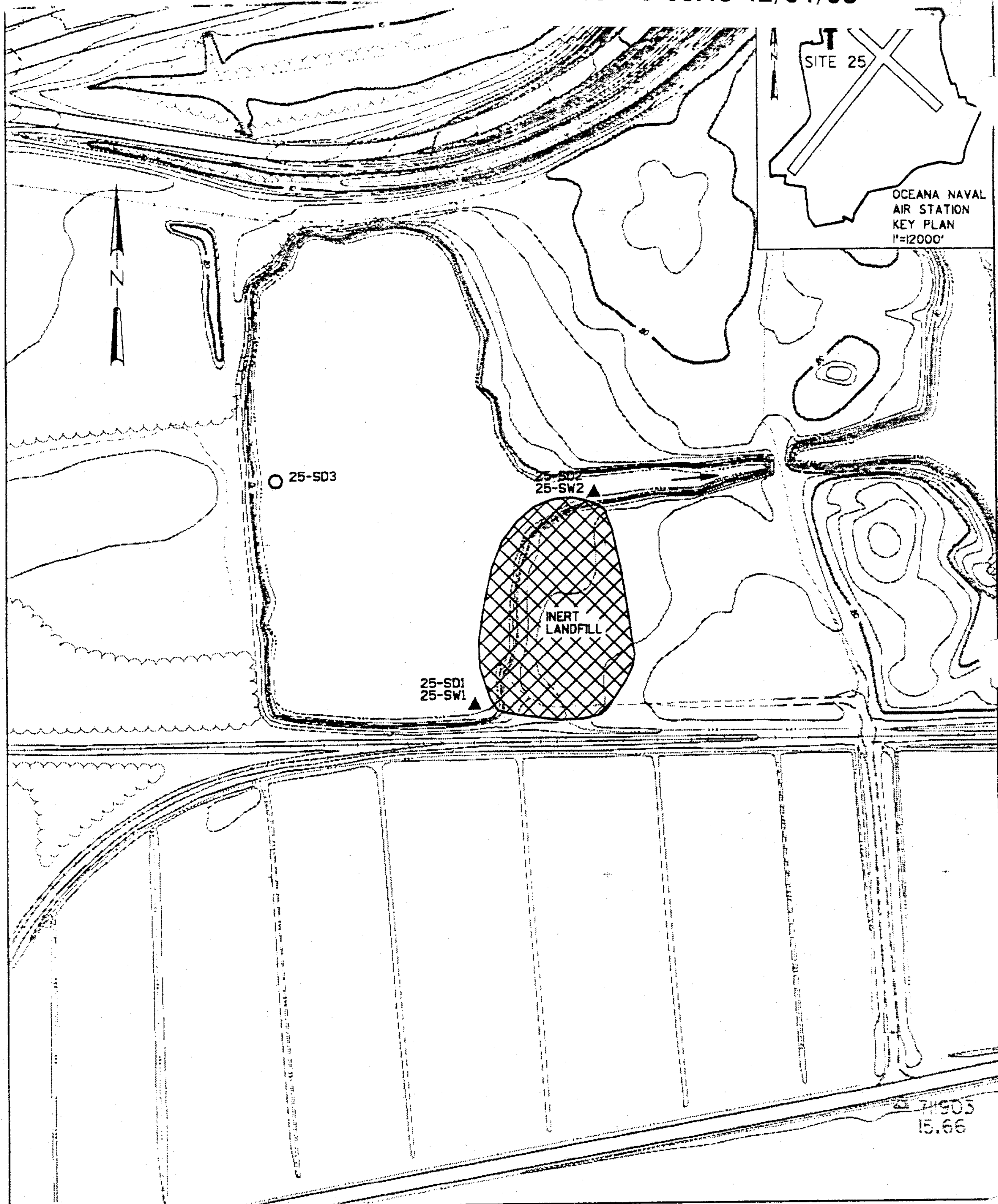

LEGEND

○ SEDIMENT SAMPLING LOCATION

▲ SEDIMENT AND SURFACE WATER SAMPLING LOCATION

APPROXIMATE LANDFILL BOUNDARY

0 100 200 300

SCALE IN FEET

Figure 4-16-1

RFI SAMPLING LOCATIONS
AT SITE 25
FEBRUARY 1993

CH2M HILL

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Environmental Setting

The Site 25 ecological study area included the inert landfill and an adjacent borrow pond and a forested area. A railroad track bounds the area to the south. The area encompasses approximately 14 acres. Figure 4-16-2 is an ecological map of the site. Much of the ground surface near the site is disturbed by excavation and fill activities associated with the landfill. The landfill is approximately 30 feet high and several hundred feet long, and spills into the adjacent pond and ditch. The topography of the area is relatively flat, except for the landfill and several large berms. Soils in the area are disturbed, fine sandy loam classified as the Udorthents soil group (see Chapter 2).

Ecology

Surface Water Resources. The large pond that abuts the landfill covers approximately 6 acres. The depth of the pond is unknown. The water in the pond, at the time of the study, appeared turbid, and was light green color, perhaps because of a high algal content. Algae mats were observed on several structural debris piles and logs in the pond. Debris in the form of cement blocks, wood, and logs was common in the pond and ditch. The ditch appears to connect the pond with an adjacent pond east of the landfill. Flow in the ditch is to the east, away from the main pond.

Wetlands. No wetlands were observed at this location during the site visit. The pond is an excavated, palustrine, open-water body. A narrow fringing scrub-shrub/forested wetland may occur along portions of the pond and ditch. Wetlands occur west of the study area, in a large forested area.

Vegetation. Much of the vegetation in the area appeared stressed, probably because of landfill activities. Weedy pioneer species dominated much of the area around the landfill. Tree species observed in the forested area include loblolly pine, tulip poplar, willow oak, northern red oak, catalpa, sumac, and waxmyrtle. Giant cane, berries, and weedy herbaceous species dominated the understory and disturbed areas.

Wildlife. A variety of birds were observed around the pond, including great blue heron, ring-necked duck, mallard ducks, kingfisher, and crows. No mammals were observed near the site. On the basis of the variety of wildlife habitat that the surrounding area provides, fox, raccoon, rodents, reptiles, and salamanders may inhabit the area. Several bluegills were observed in the pond. Largemouth bass also may inhabit the pond.

Geologic and Hydrogeologic Conditions

No soil samples were collected at Site 25 and no monitoring wells have been installed; therefore, there is no precise information on the geology of this site. It is reasonably inferred that the geologic conditions at this site are consistent with the local and regional geologic conditions about which more is known. The large unlined pond and the creek that drains from the pond may receive groundwater from the surrounding area.

Contamination and Extent

Sediment and surface water samples were collected from Site 25 and submitted for organic and inorganic analyses. Samples 25-SD2 and 25-SW2 were analyzed for Appendix IX constituents. Other samples were analyzed for metals, pesticides/PCBs, volatiles, and semivolatiles. Tables 4-16-1 through 4-16-3 present the analytical laboratory results.

Sediment

Nine semivolatile organic compounds were detected in the sediment samples at Site 25, notably in 25-SD1 and 25-SD2; however, all compounds were detected below their quantitative detection limits. All of the semivolatiles were compounds typically found in fuels and oils.

Pesticides were detected in 25-SD1. The pesticide compounds detected in sediment were dieldrin (56 ppb), 4,4'-DDE (27 ppb), and 4,4'-DDT (25 ppb). No volatile organic compounds, organophosphorus pesticides, herbicides, or dioxin/furan compounds were detected in 25-SD2.

The inorganic analyses of the Site 25 sediments detected several heavy metals at low concentrations. The list of detections includes arsenic, barium, beryllium, chromium, copper, cobalt, lead, vanadium, zinc, and tin.

Surface Water

The Site 25 surface-water samples (25-SW1 and 25-SW2) were analyzed for the same parameters as the sediments. The results of the organic analyses, which are presented in Table 4-16-2, revealed that no organic compounds were above the detection limits in surface water.

Volatiles detected included very low levels of benzene (1 ppb) and toluene (2 ppb) in 25-SW2 at concentrations below the quantitative detection limits. Three semivolatile compounds were detected in 25-SD1, and one was detected in 25-SD2, all at concentrations below quantitative detection limits. No organophosphorus pesticides, herbicides, pesticide/PCBs, or dioxin/furan were detected in 25-SW2.

Heavy metals detected in the Site 25 surface-water samples included arsenic, barium, copper, nickel, iron, and zinc (Table 4-16-3). The concentrations of these metals did not exceed RCRA criteria and standards.

Health and Environmental Assessment

Table 4-16-4 lists concentrations above potentially applicable standards and criteria. Concentrations of 4,4-DDE (27 ppb) and 4,4-DDT (25 ppb) in the sediment at Site 25

LOCATION OF DEBRIS LANDFILL IS APPROXIMATE

Figure 4-16-2
ECOLOGICAL MAP FOR SITE 25 NAS OCEANA

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Table 4-16-1
ORGANIC COMPOUNDS IN THE SEDIMENT AT SITE 25
February 1993
(All data in ppb)

Analyte	25-SD1	25-SD2	25-SD3
Volatile Organic Compounds			
Methylene chloride	12 b	10 b	18 b
Acetone	6 j	39	20
Semivolatile Organic Compounds			
Di-n-butylphthalate	240 bj	140 bj	52 bj
Phenanthrene	*	93 j	*
Fluoranthene	89 j	120 j	*
Pyrene	110 j	110 j	*
Benzo(b)fluoranthene	97 j	43 j	*
Benzo(k)fluoranthene	88 j	*	*
Benzo(a)anthracene	75 j	*	*
Chrysene	120 j	*	*
bis(2-ethylhexyl)phthalate	55 j	*	*
Pesticide/PCB Compounds			
Dieldrin	56	*	*
4,4' DDE	27	*	*
4,4' DDT	25	*	*
Organophosphorous Pesticide Compounds	NA	*	NA
Herbicide Compounds	NA	*	NA
Dioxin/furan Compounds	NA	*	NA

Notes:

All volatile, semivolatile, pesticide/PCB, organophosphorus pesticide, herbicide, and dioxin/furan compounds not listed in the table above were analyzed for but not detected.
25-SD2 was submitted for the full series Appendix IX analysis of all parameters listed above.
b - This compound was found in the associated laboratory blank as well as the sample.
j - This is an estimated value because it was detected below the accurately quantitative detection limit.
* - The compound was analyzed for, but not detected.
NA - Not Analyzed.

Table 4-16-2
ORGANIC COMPOUNDS IN THE SURFACE WATER AT SITE 25
February 1993
(All data in ppb)

Analyte	25-SW1	25-SW2
Volatile Organic Compounds		
Methylene chloride	2 b	5 b
Acetone	5 j	9 bj
Benzene	*	1 j
Toluene	*	2 j
Semivolatile Organic Compounds		
bis(2-ethylhexyl)phthalate	*	2 j
Naphthalene	3 j	*
2-Methylnaphthalene	6 j	*
Pesticide/PCB Compounds	*	*
Organophosphorous Pesticide Compounds	NA	*
Herbicide Compounds	NA	*
Dioxin/furan Compounds	NA	*

Notes:

All volatile, semivolatile, pesticide/PCB, organophosphorus pesticide, herbicide, and dioxin/furan compounds not listed in the table above were analyzed for but not detected.

b - This compound was found in the associated laboratory blank as well as the sample.
j - This is an estimated value because it was detected below the accurately quantitative detection limit.
* - The compound was analyzed for, but not detected.
NA - Not Analyzed.

Table 4-16-3
INORGANICS IN SURFACE WATER AND SEDIMENT AT SITE 25
February 1993

Analyte	Sediment (mg/kg)			Surface Water (µg/l)	
	25-SD1	25-SD2	25-SD3	25-SW1[a]	25-SW2[a]
Aluminum	4,230	NA	2,270	288 +	NA
Antimony	<4.5	<3.9 n	<3.8 n	<16.4	<16.4
Arsenic	0.65 b	0.91 b	1.0 b	0.88 b,n	1.2 b,n
Barium	17.7 b	17.4 b	7.5 b	38.5 b	38.2 b
Beryllium	0.14 b	0.17 b	0.07 b	<0.26	<0.26
Cadmium	1.3	<0.65	<0.65	<2.8	<2.8
Calcium	689	NA	73.2 b	37,100	NA
Chromium	6.0	4.3	3.9	<2.8	<2.8
Cobalt	<0.75	1.2 b	0.86 b	<2.6	<2.6
Copper	746	2.1 b	1.2 b	2.7 b	2.9 b
Iron	2,200	NA	1,240	399 #	NA
Lead	3.7	7.2 +	2.4 +	<1.7 n	<1.7 n
Magnesium	376 b	NA	205 b	6,500	NA
Manganese	15.0	NA	8.1	29.7	NA
Mercury	<0.07	<0.03	<0.03	<0.07	<0.07
Nickel	4.7 b	<2.2	<2.2	13.7 b	<9.4
Potassium	295	NA	<218	10,600	NA
Selenium	0.45 b	<0.44	<0.43	<1.8 w,n	<1.8 n
Silver	<0.31	<0.47	<0.47	<2.0	<2.0
Sodium	NA	NA	152 b	26,200	NA
Thallium	<0.42	<0.55	<0.54	<2.3	<2.3
Vanadium	6.9 b	5.7 b	3.7 b	<2.6	<2.6
Zinc	723	9.0	4.9	<9.0	15.7 b
Tin	NA	3.8 b	NA	NA	<12.7
Cyanide	NA	<0.08	NA	NA	<1.4

Notes:

<The constituent was not detected at this instrument detection limit.
25-SD2 and 25-SW2 were submitted for Appendix IX metals analysis.
[a]The nondetect results of selenium were rejected during the data validation process because of low spike recoveries less than 30 percent.
b = The reported value obtained was less than the contract required detection limit (CRDL), but greater than or equal to the IDL.
n = Spiked sample recovery not within control limits.
+ = Duplicate analysis not within control limits.
W = Post digestion spike for furnace AA analysis is out of control limits (85 to 115%), while sample absorbance is less than 50% of spike absorbance.
# = Laboratory duplicate had poor precision; therefore, the value should be considered an estimate.

Table 4-16-4
CONSTITUENTS DETECTED IN THE SEDIMENT AND SURFACE WATER AT SITE 25 THAT EXCEEDED POTENTIALLY APPLICABLE FEDERAL GUIDELINES
(All data in ppb)

Compound	Location	Concentration	NOAA ER-M Sediment Guidelines	Human Health Criteria for Ingestion of Water and Fish	Proposed RCRA Action Levels
DDT	25-SD1	25	7	NA	2,000
DDE	25-SD1	27	15	NA	2,000
Zinc	25-SD1	723,000	270,000	NA	NS
Copper	25-SD1	746,000	390,000	NA	NS
Arsenic	25-SW1 25-SW2	0.88 1.2	NA	0.0022	50
Iron	25-SW1	399	NA	300	NS
Nickel	25-SW1	13.7	50,000	13.4	700

Notes:

Compounds that were detected and exceeded potentially applicable guidelines are included in this table.
The NOAA possible effects range median were extracted from Long and Morgan, National Oceanic and Atmospheric Administration, 1991.
NA = Not applicable to the medium sampled.
NS = No standard.

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exceeded the NOAA sediment guidelines of 15 ppb and 7 ppb, respectively. The proposed ecological sediment standard for the protection of benthic organisms is 9.0 μg of dieldrin per gram of organic carbon. The organic carbon content of the sediment was not measured; however, at 1 percent organic carbon, this standard translates to a proposed criterion of 90 μg/kg (ppb). The concentration of dieldrin in sediment in 25-SD1 of 56 ppb is below this potential criterion.

The inorganics detected in the sediment at Site 25 that exceeded federal guidelines are zinc (723 ppm) and copper (746 ppm). These concentrations exceed the NOAA sediment guidelines of 270 and 390 ppm, respectively.

Arsenic and nickel concentrations in the surface-water samples exceeded the federal ambient water quality criteria (AWQC) for the ingestion of water and fish. Beryllium and silver were not detected in surface water. The iron concentration in 25-SW1 also exceeded the water and fish ingestion criterion; however, the analysis of the corresponding laboratory duplicate had poor precision; therefore, the 399 ppb should be considered an estimated value.

From an ecological perspective, the organic and inorganic analytes detected in the surface water and sediment at Site 25 did not exceed established criteria, with the exception of arsenic in surface water. The concentrations of arsenic exceeded the human-health criteria for water and fish ingestion in surface water of 0.0022 ppb. This standard is used as a conservative basis for estimating exposures to terrestrial organisms from surface water absence of other surface water standards for animals. The fresh-water chronic exposure criterion for arsenic is 190 ppb, well above the maximum of 1.2 ppb observed in Site 25 surface water. Cadmium, mercury, and silver were not detected in surface water at their respective instrument detection limits of 2.8, 0.07, and 2.0 ppb. The standard instrument detection limits for mercury and cadmium are above federal AWQC. Aluminum AWQCs are dependent on pH, which was not measured in the field. See Appendix A for an explanation of the use of standards for terrestrial organisms.

Fate and Transport

CH2M HILL has no data to show whether the pond discharges to or receives groundwater but the surface-water and groundwater systems likely are interconnected. Some surface water was seen flowing out from the pond during the RFI so transport of sediment and surface water via the ditch is a potential transport mechanism. However, in light of the analytical data, this transport is not likely to be significant.

Although the concentrations of 4,4-DDE and 4,4-DDT in the sediments at Site 25 exceed the NOAA guidelines, the presence of these compounds must be considered in light of nearby land use. The large field adjacent to the inert landfill has been used for farming for many years. This suggests that pesticides applied to the nearby field may be the source of pesticide contamination in the pond. The pesticides could have been transported to the pond by the flow of surface water or groundwater along with windblown dust.

Recommendations

Because pesticides and metals are present in sediment at concentrations above ecological guidelines, additional sampling of the pond sediment is recommended to determine the extent of contamination. A more detailed analysis of ecological risk may be necessary depending on the results of this additional sampling.

Site 26—Fire-Fighting Training Area, Building 220

Site Location and History

Site 26 is a burn pit southeast of Building 220, the base's fire station (see Figure 4-17-1). The burn pit is a shallow gravel-covered depression that was used for portable fire extinguisher training. POL and fuel-contaminated objects were placed in the P-4 and were ignited. Burn residue and water was periodically pumped out of the pit to the surrounding soils (RFA, 1988). During the VSI, inspectors observed that staining on the ground extended to a nearby drainage ditch (RFA, 1988). The burn pit had no release controls at the time of the VSI (RFA, 1988). The pit has been filled and returned to grade since at least 1990. The assistant fire chief informed CH2M HILL that the pit was a 3-foot by 4-foot metal pan inset approximately 4 inches below grade (Kline, 1993).

Past Investigations and RFI Site Activities

There has been no previous environmental sampling at Site 26. The purpose of the RFI activities at Site 26 was to characterize the soils near the training pit. Five soil samples were collected at this site (see Figure 4-17-1). Sample 26-SS3 was collected in the pit and samples 26-SS1 and 26-SS2 were collected slightly down the slope. The fourth and fifth sampling locations (26-SS4 and 26-SS5) were in the ditch. Sample 26-SS4 was collected in the ditch upstream of the burn pit, and sample 26-SS5 was downstream of the pit. Samples were collected from areas of visible staining where possible.

The field investigation included the use of an OVM photoionization detector to screen samples from 0.5 to 1.0 foot and 2.0 to 3.0 feet at each sampling location. The five most contaminated samples were sent to the CH2M HILL laboratory in Montgomery, Alabama, for confirmatory analysis of VOCs, PAHs, TPH, metals, and ignitability. At the Site 26 sampling locations, the deepest soil sample from 2.0 to 3.0 feet was typically submitted for analysis, except for at 26-SS3, where the shallower sample from 0.5 to 1.0 foot was submitted

Environmental Setting

Site 26 includes an asphalt parking lot behind the fire station, a mowed grass area, and a ditch to the southeast. Some forested areas are nearby. A part of the area southeast of the ditch was disturbed because of ongoing construction of aircraft support buildings during the RFI. Figure 4-2-2 in the Site 2B section of this chapter is an ecological map that shows Site 26.

A steam pipeline traverses the northern corner of the study area. Aside from the slight southeasterly slope from the pit to the ditch, the study area is flat. No water resources exist within the study area. Surface flows generally are directed to the ditch to the southeast. This ditch flows very gently to the northeast.

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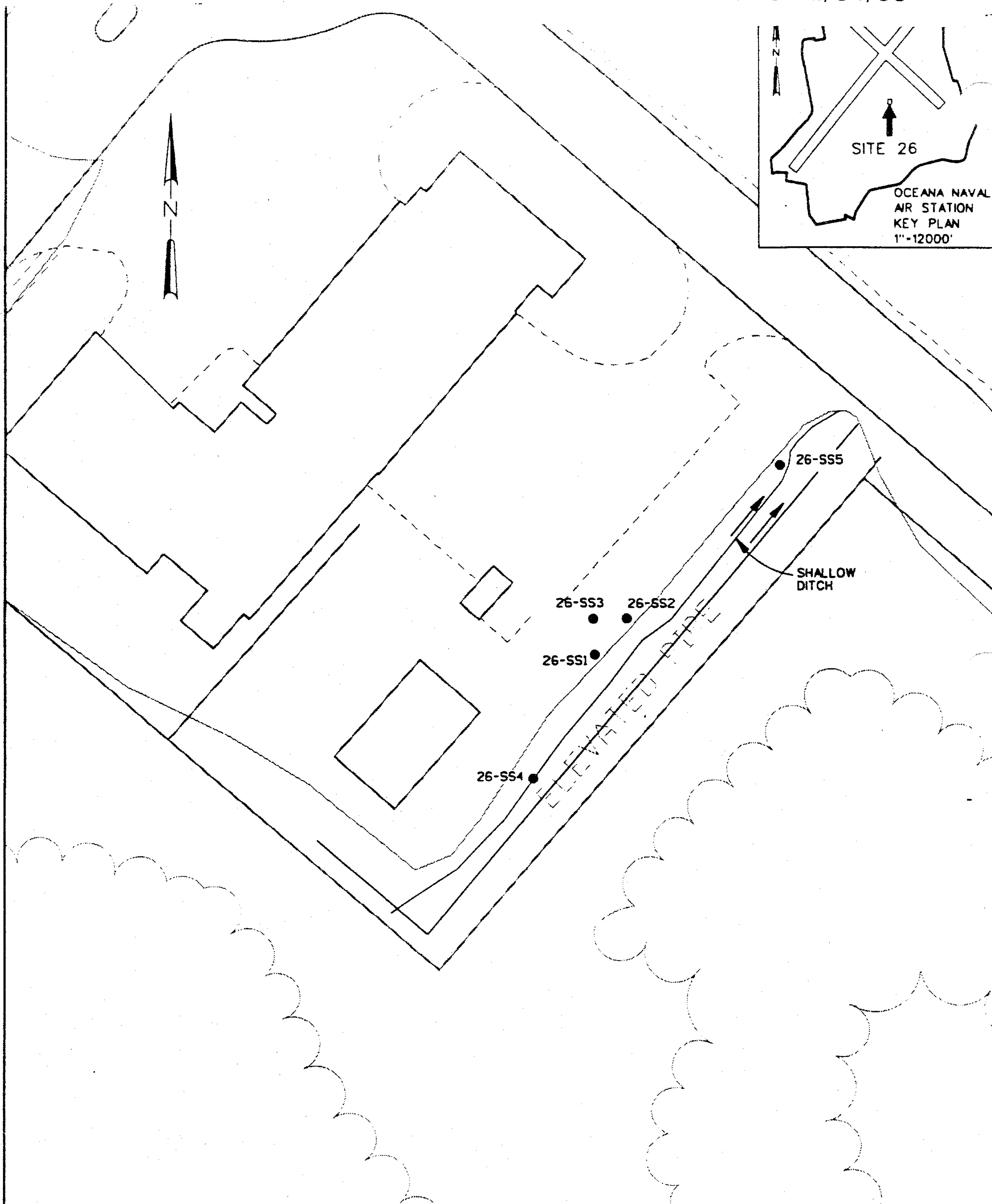

LEGEND

- ● SOIL SAMPLING LOCATION
- ← DIRECTION OF SURFACE WATER FLOW

0 25 50 75

SCALE IN FEET

Figure 4-17-1

RFI SAMPLING LOCATIONS
AT SITE 26
JANUARY 1993

0368k261.dgn
23-Dec-1993

The entire study area down the slope from the pit is palustrine forested wetland as shown in Figure 2-5 in Chapter 2. At the time of the study, the surface soil was moist and several shallow ponded or saturated linear depressions occur under the steam pipeline. The soils are classified as Acredale urban silty loam. Vegetation in these areas was dominated by grasses. The vegetative community is dominated by forest species including southern red oak, willow oak, sweet gum, laurel oak, swamp white oak, and red maple. Several trees had been cut down because of ongoing development in the area. No other signs of stress were observed. No wildlife was observed in the study area. Signs of the presence of nesting birds and mammals occur in several trees throughout the area, including squirrel's leaf nests, crow's nest, and several den holes in a large dead tree.

The surficial soils observed during sampling are sandy silts underlain by silty sands. Beyond the 3-foot depth to which hand augers penetrated during soil sampling, the geology is unknown. There is no hydrogeologic data for this site.

Contamination and Extent

The laboratory results indicate several types of constituents including TPH, PAHs, and volatile organic compounds. Table 4-17-1 presents the organic laboratory results for the five samples. All soil samples contained TPH, with the highest concentrations in the deeper soil samples (26-SS2, 26-SS4, and 26-SS5) where the TPH results were 140,000 ppb, 166,000 ppb, and 153,000 ppb, respectively. The lowest TPH concentration was in 26-SS3, which is the sample collected from the shallow depth. The high TPH concentrations in 26-SS4 and 26-SS5 are explained by field observations of a black sheen throughout the drainage ditch. The drainage in the ditch is poor and water ponds 1 or 2 inches deep and 1 or 2 feet wide from 26-SS4 to the northeast end of the ditch when full. Hydrocarbons discharged to the ditch, therefore, are free to spread out to both upstream and downstream locations.

PAHs were detected only in the duplicate sample of 26-SS2. The PAH compounds detected include naphthalene (43 ppb), 2-methylnaphthalene (100 ppb), and 1-methylnaphthalene (48 ppb), all of which were low.

Several VOCs were detected at Site 26; however, all VOCs were well below proposed RCRA action levels and most were below quantitative detection limits. Methylene chloride, acetone, and total xylene were detected in all samples. 1,1-DCE, TCE, and chlorobenzene were detected in 26-SS3 at 5 ppb, 4 ppb, and 5 ppb, respectively. 2-butanone was found in 26-SS1 (15 ppb) and the duplicate of 26-SS2 (28 ppb). Toluene and benzene were detected in 26-SS1 and 26-SS3, and toluene was detected in the duplicate of 26-SS2. Carbon disulfide was detected below the quantitative detection limit in 26-SS1, 26-SS2, 26-SS4, and 26-SS5.

Table 4-17-1
ORGANIC COMPOUNDS IN THE SOILS AT SITE 26
January 1993
(All data in µg/kg)

Analyte	Detection Limit	26-SS1 2.0-3.0 ft.	26-SS2[a] 2.0-3.0 ft.		26-SS3 0.5-1.0 ft.	26SS4 2.0-3.0 ft.	26-SS5 2.0-3.0 ft.
			Initial	Duplicate			
TPH	900	71,700	140,000	149,000	7,600	166,000	153,000
Polynuclear Aromatics							
Naphthalene	50	*	*	43 J	*	*	*
2-Methylnaphthalene	50	*	*	100	*	*	*
1-Methylnaphthalene	50	*	*	48 J	*	*	*
Volatile Organic Compounds							
Methylene Chloride	5	37 B	20 B	46 B	11 B	25 B	24 B
Acetone	10	45 B	83	140	47	37	32
1,1-Dichloroethylene	5	*	*	*	5 J	*	*
Trichloroethylene	5	*	*	*	4 J	*	*
Benzene	5	2 J	*	*	5 J	*	*
Toluene	5	4 J	*	2 J	5 J	*	*
Chlorobenzene	5	*	*	*	5 J	*	*
Xylene (Total)	5	2 J	5 J	12	5 J	11	10
Carbon Disulfide	5	1 J	*	4 J	*	2 J	2 J
2-Butanone (MEK)	10	15	*	28	*	*	*

Notes:
All volatile organic and polynuclear aromatic compounds not listed above were analyzed, but were not detected in any samples.
All samples were collected from a depth of 2-3 feet, except 26-SS3 which was collected from 0.5 to 1.0 foot.
QC sampling in 26-SS30 is duplicate of 26-SS2.
[a]The field duplicate VOC and PAH results were in poor correlation with the initial sample results as determined by the data validation process. No qualification was performed.
J Estimated value.
* The compound was below the detection limit.
B Compound found in laboratory blank as well as sample.

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The results of soils analysis for inorganic metals and ignitability are listed in Table 4-17-2. Most inorganic compounds detected in the samples are common soil constituents. Several heavy metals at low concentrations were present. All soil samples were determined by laboratory analysis to be non-ignitable.

Health and Environmental Assessment

No VOCs detected at Site 26 exceeded applicable human-health or environmental soil criteria. No health-based criteria or RCRA action levels are available for the detected PAHs; however, the RBC for naphthalene in residential soils is 3,100,000 ppb. This screening concentration was not exceeded at Site 26. The TPH concentrations at 26-SS2 (140,000 ppb), 26-SS4 (166,000 ppb), and 26-SS5 (153,000 ppb) exceeded the established Virginia guideline of 100,000 ppb.

The only inorganic compound that exceeded the established RCRA criteria at Site 26 is beryllium, which was detected in all soil borings above its health-based criterion for carcinogens of 0.143 ppm. However, all concentrations were below the quantitative detection limit and all but one were below average background concentrations of beryllium in the eastern United States (Shacklette and Boerngen, 1984). Arsenic exceeded the carcinogenic RBC in most samples. The average background concentration of arsenic in the eastern United States (4,800 ppb) also exceeds the carcinogenic RBC standards for residential (680 ppb) and commercial/industrial soils (1,600 ppb). The arsenic concentration in soil sample 26-SS3 (14,000 ppb) was above the mean in the eastern United States and both carcinogenic RBCs but was below noncarcinogenic RBCs for residential (23,000 ppb) and commercial/industrial soil (310,000 ppb). Because the soil contamination at Site 26 is generally greatest at 2 to 3 feet, ingestion of beryllium and arsenic by humans is not likely.

Fate and Transport

The principle potential pathways for offsite migration from Site 26 are surface water and groundwater transport. The contamination observed in the ditch suggests that hydrocarbons have already migrated from the burn pit to the ditch and could be transported farther down the stormwater drainage system. The ditch at Site 26 probably discharges to a culvert that drains to the ditch flowing past Site 2B. As mentioned previously, the upstream locations in the Site 2B ditch show some contamination but it is probably not caused by Site 26 discharges alone.

Shallow groundwater also may receive contaminated water that has infiltrated through the unsaturated zone and picked up mobile contaminants. Most oil and fuel constituents that are known to be mobile (i.e., BTEX compounds) were present at very low concentrations in the Site 26 soils. Because these samples were screened with an OVM and were collected in the pit and ditch, they were collected from intervals with a maximum potential

Table 4-17-2
IGNITABILITY AND INORGANIC COMPOUNDS IN SOILS AT SITE 26
January 1993
(All data in mg/kg)

Analyte	26-SS1	26-SS2*		26-SS3*	26-SS4*	26-SS5*
	2.0-3.0 ft.	2.0-3.0 ft.		0.5-1.0 ft.	2.0-3.0 ft.	2.0-3.0 ft.
		Initial	Duplicate			
Alumimum	7,710	13,600	12,300	12,100	29,700	22,900
Antimony	<3.9	<1.2	<4.0	<3.7	<4.3	<4.6
Arsenic	1.5 B	2.1 B	2.2 B	14.0	4.2	3.2
Barium	33.6 B	53.3	53.1	68.3	87.4	81.0
Beryllium	0.31 B	0.54 B	0.48 B	0.41 B	1.2 B	0.83 B
Cadmium	<0.65	<0.70	<0.67	<0.62	<0.72	<0.77
Calcium	336 B	825 B	790 B	1,370	479 B	370 B
Chromium	8.5	16.2	13.8	13.9	36.0	40.8
Cobalt	1.7 B	2.2 B	2.0 B	4.3 B	4.4 B	5.2 B
Copper	3.4	6.1 B	6.6	15.6	11.2	13.2
Iron	4,430	7,120	6,400	13,100	15,000	24,300
Lead	4.8	10.3	7.1	20.6	14.1	21.1
Magnesium	462 B	755 B	676 B	1,070 B	1,090 B	1,980
Manganese	20.5	26.2	30.8	235	19.6	31.7
Mercury	0.04 B	<0.03	0.05 B	0.13	<0.04	<0.04
Nickel	4.0 B	7.5 B	5.3 B	8.6 B	13.4	12.9
Potassium	437 B	625 B	635 B	1,860	972 B	1,130 B
Selenium	<0.44	0.79 B	0.52 B	<0.41	0.86 B	0.60 B
Silver	<0.47	<0.51	<0.49	<0.45	<0.52	<0.56
Sodium	276 B	284 B	276 B	319 B	300 B	555 B
Thallium	<0.55	<0.59	<0.57	<0.52	<0.61	<0.65
Vanadium	9.9 B	19.2	16.6	18.3	60.8	34.8
Zinc	11.8	16.2	13.9	36.1	20.4	35.4
Ignitability	non-ignitable	non-ignitable	non-ignitable	non-ignitable	non-ignitable	non-ignitable

Notes:

QC sampling - 26-SS30 is a duplicate of 26-SS2
*The nondetect results of antimony were rejected during the data validation process because of spike recoveries less than 30 percent.
B Reported value is less than the CRDL, but greater than or equal to the IDL
< The constituent was not detected at this IDL.

for contamination. Below 3 feet, the degree of contamination remains unknown, however. Some spreading of contamination within the ditch in response to fuel properties probably has occurred and may still occur. As sheet flow carries contaminants to the standing surface water in the drainage ditch, the surface water may act as an additional transport medium. This may explain the presence of organic contaminants at 26-SS4, which is upstream in the ditch. Contaminants at 26-SS4 upstream in the ditch may result from periods of low flow when the standing water allows contaminants to spread out in a sheen. As the standing water evaporates or infiltrates into the bottom of the drainage ditch, the length of the ditch is contaminated with a small amount of fuel constituents.

Recommendations

The possibility of downstream contamination in the surface water flow system has already been addressed by the Site 2B sampling program. TPH concentrations at 2 to 3 feet are slightly above Virginia guidelines. Shallower soils had lower OVA readings and, therefore, are believed to be less contaminated. Because there was not VOC, semivolatile, or metals contamination above standards in any of the soil samples and the TPH was slightly above guidelines only in soils from 2 to 3 feet, the threat to human beings or the environment appears minimal. However, if in the future the potential arises for contaminants to be brought to the surface during construction activities, the U.S. Navy should exercise caution to minimize risk to construction workers. No further action at Site 26 is recommended.

WDCR705/030.51

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Appendix A
Ecological Study and Assessment

Ecological Study

Introduction

An onsite ecological study was conducted in December 1992 by a CH2M HILL ecologist. Most of the results are presented in the 17 site sections in Chapter 4 of the *RCRA Final Report*. However, procedural descriptions and other background data are presented in this appendix. The ecological study describes the general environmental setting of the base, characterizes the ecology near each site, and identifies environmental receptors most likely to be exposed to site contaminants. Evidence of stress (e.g., stressed or dead vegetation, bare soil, and erosion), if present, also was noted. Table A-1 lists plant species and Table A-2 lists terrestrial and aquatic species of wildlife observed during the study. Many species of wildlife, in particular birds, were not present during the onsite ecological study because the study was conducted in the late fall and early winter season when many species are hibernating or have migrated to their wintering grounds. In addition, identifying plant species observed on the site was difficult because of the lack of foliage or other identifying characteristics. Therefore, this appendix includes lists of plant and wildlife species observed as well as species likely to occur at Oceana or in the Virginia Beach area.

Literature Review

The ecological study included reviewing related environmental documents, including:

- Aerial photographs
- Wetlands map of NAS Oceana (U.S. Fish and Wildlife Service (FWS) and the Department of Navy, 1991)
- USFWS National Wetland Inventory (NWI) Maps
- NAS Oceana's Fish and Wildlife Management Plan (1988)
- NAS Oceana's Fishery Management Report (FWS, 1990)
- Initial Assessment Study of Oceana (RGH, 1984)
- NAS Oceana's Historic and Archeological Resources Protection Plan (1990)
- Inventory of Rare, Threatened, and Endangered Species of Oceana (Virginia Department of Natural Heritage, Report #90-6; DNH 1990),
- NAS Oceana's Natural Resources Conservation Plan (1993)

Table A-1
VEGETATION OBSERVATIONS
NAS OCEANA
December 1992

Common Name	Scientific Name	Wetland Indicator	Location Observed
Grasses, Sedges, and Rushes			
Lawn grasses	*Graminae spp.*	N/A	2C, 2D, 2E, 1, 11, 15, 21, 23, 24, 26
Clubrush	*Scirpus sp.*	OBL	1, 11, 22
Spikerush	*Eleocharis sp.*	OBL	2D, 1, 11, 15, 22
Wool grass	*Scirpus cyperinus*	OBL	1, 11, 15
Olney's bulrush	*Scirpus americanus*	OBL	1, 11
Three-square bulrush	*Scirpus pungens*	OBL	1, 11, 15
Yellow-eyed grass	*Xyris sp.*	OBL	1, 11, 15
Soft rush	*Juncus effusus*	FACW+	2D, 1, 11, 22
Canada rush	*Juncus canadensis*	OBL	1, 11, 15, 22, 25
Switch grass	*Panicum virgatum*	FAC	15, 22
Rush	*Juncus sp.*	FACW	15, 22
Broom sedge	*Andropogon virginicus*	FACU	2B, 2C, 1, 11, 15, 21, 22, 23, 24, 25
Plume grass	*Erianthus alopecuroides*	FAC	2B, 1, 11, 15, 25
Panic grass	*Dicanthelium spheaerocarpon*	FACU	2B, 1, 11, 15
Foxtail grass	*Setaria sp.*	FAC	1, 11, 15, 25
Paspalum grass	*Paspalum sp.*	N/A	2B, 1, 11, 15
Southern waxy sedge	*Carex glaucescens*	OBL	1, 11
Giant cane	*Arundinaria gigantea*	FACW	2B, 2C, 2D, 1, 11, 15, 16, 21, 22, 23, 24, 25

Table A-1
VEGETATION OBSERVATIONS
NAS OCEANA
December 1992

Common Name	Scientific Name	Wetland Indicator	Location Observed
Trees, Shrubs, and Vines			
Sweet gum	*Liquidambar styraciflua*	FAC	2B, 2C, 2D, 1, 11, 15, 16, 18, 21, 22, 24, 25, 26
Blackberry	*Rubus sp.*	UPL	2B, 1, 11, 15, 22, 25
Loblolly pine	*Pinus taeda*	FAC-	2B, 2C, 1, 11, 15, 19, 20, 21, 22, 23, 24, 25
Black gum	*Nyssa sylvatica*	FAC	1, 11, 15, 22, 25
American beech	*Fagus grandifolia*	FAC+	2B, 16
Black cherry	*Prunus serotina*	FACU	2B, 2C, 1, 11, 15, 22, 25
Waxmyrtle	*Myrica cerifera*	FAC	2B, 2C, 1, 11, 15, 21, 22, 23, 24, 25
Hercules club	*Zanthoxylum clava-herculis*	FAC	1, 11, 15, 22, 25
Shagbark hickory	*Carya ovata*	FACU-	1, 11
Black oak	*Quercus velutina*	UPL	1, 11
American basswood	*Tilia americana*	FACU	1, 11
American holly	*Ilex opaca*	FACU+	16, 26
Winged sumac	*Rhus coppalina*	NI	25
Catalpa tree	*Catalpa sp.*	FAC	25
Cherrybark oak	*Quercus falcata (variety) pagodafolia*	FACW	1, 2C, 11
Paw paw	*Asimina triloba*	FACU+	2B, 2C, 16
Longleaf pine	*Pinus palustris*	N/A	22
Black willow	*Salix nigra*	FACW+	22

Table A-1
VEGETATION OBSERVATIONS
NAS OCEANA
December 1992

Common Name	Scientific Name	Wetland Indicator	Location Observed
Blackjack oak	*Quercus marilandica*	N/A	2B, 18, 26
Red maple	*Acer rubrum*	FAC	2B, 2C, 2D, 1, 11, 15, 19, 20, 21, 22, 23, 24, 25, 26
Southern red oak	*Quercus falcata*	FACU-	2B, 2C, 2D, 1, 11, 15, 16, 19, 20, 21, 22, 23, 24, 25, 26
Sweetbay magnolia	*Magnolia virginiana*	FACW+	2B, 1, 11, 25
Swamp chesnut oak	*Quercus michauxii*	FACW	2B, 2C, 1, 11, 25, 26
Choke cherry	*Prunus virginiana*	FACU	2C, 15, 25
Japanese honeysuckle	*Lonicera japonica*	FAC-	2B, 2C, 2D, 1, 11, 15, 21, 22, 23, 24, 25
Hop hornbeam	*Ostrya virginiana*	FACU-	2C, 25
Tulip poplar	*Liriodendron tulipifera*	FACU	2C, 1, 11, 15, 16, 22, 23, 24, 25
Greenbriar	*Smilax rotundifolia*	FAC	2C, 2D, 1, 11, 15, 21, 22, 23, 24, 25
Ironwood	*Carpinus caroliniana*	FAC	2c,1,11,22,25
Eastern red cedar	*Juniperus virginiana*	FACU	2C, 2D, 1, 11, 15, 22, 25
Groundsel tree	*Baccharis halmifolia*	FACW	2C, 15, 22
Highbush blueberry	*Vaccinium corymbosum*	FACW-	2C, 22, 25
Laurel oak	*Quercus laurifolia*	FACW-	2C, 26
Willow oak	*Quercus phellos*	FAC+	2C, 22, 25, 26
Elderberry	*Sambucus canadensis*	FACW-	1, 11, 22, 25
Multiflora rose	*Rosa multiflora*	FACU	15, 25

Table A-1
VEGETATION OBSERVATIONS
NAS OCEANA
December 1992

Common Name	Scientific Name	Wetland Indicator	Location Observed
Mimosa tree	*Albizia julibrisson*	UPL	15
Bitternut hickory	*Carya cordiformis*	FACU+	15
California privet	*Ligustrum ovafolium*	UPL	15
Common privet	*Ligustrum vulgare*	FACU	15
Fringe tree	*Chionanthus virginicus*	FAC+	1, 11, 15
Other Herbaceous Vegetation			
Goldenrod	*Solidago sp.*	N/A	2B, 1, 11, 15, 22
Water plantain	*Alisima-plantago aquatica*	OBL	2D
Glasswort	*Salicornia*	--	22
Marsh purselane	*Ludwigia palustris*	OBL	2D, 1, 11, 15, 22
Aster	*Aster sp.*	N/A	1, 11, 15, 22, 25
Cattail	*Typhus latifolia*	OBL	2D
Seedbox	*Ludwigia alterniflora*	OBL	15, 22, 25
Alligator weed	*Polygonum sp.*	FACW	15
False nettle	*Boehmeria cylindrica*	FACW+	1, 11

Table A-2
WILDLIFE OBSERVATIONS*
NAS OCEANA
December 1992

Common Name	*Scientific Name*	Location Observed
Mammals		
White-tailed deer	*Odocoileus virginianus*	1, 2B, 2C, 11, 15, 19, 20, 21, 22, 23, 24, 25
Raccoon	*Procyon lotor*	1, 2B, 11, 15, 16, 19, 20, 21, 22, 23, 24, 25
Red fox	*Vulpes vulpes*	1, 11, 15
Grey fox	*Urocyon cinereoargenteus*	1, 11, 15, 22
Woodchuck	*Marmota monax*	1, 2B, 11, 15
Muskrat	*Ondatra zibethicus*	1, 11, 15, 22
Opossum	*Didelphis virginiana*	1, 11, 15, 22, 25
Eastern cottontail	*Sylvilagus floridanus*	1, 2B, 2C, 11, 15, 16, 19, 20, 21, 22, 23, 24, 25
Eastern chipmunk	*Tamias striatus fisheri*	1, 2B, 2C, 11, 15, 16, 19, 20, 21, 22, 23, 24, 25
Field mouse	*Peromyscus sp.*	1, 2B, 2C, 11, 15, 16, 19, 20, 21, 22, 23, 24, 25
Reptiles/Amphibians		
Eastern painted turtle	*Chrysemys p. picta*	25
Chorus frog	*Pseudacris sp.*	22
Spring peeper	*Hyla crucifer*	22
Green frog	*Rana clamitans*	1, 11, 16, 22, 25
Birds		
Yellow-rumped warbler	*Dendroica coronata*	1, 2B, 2C, 11, 15, 19, 20, 21, 22, 23, 24, 25, 26
Northern cardinal	*Cardinalis cardinalis*	1, 2B, 2C, 2D, 11, 15, 19, 20, 21, 22, 23, 24, 25, 26

Table A-2
WILDLIFE OBSERVATIONS*
NAS OCEANA
December 1992

Common Name	*Scientific Name*	Location Observed
American robin	*Turdus migratorius*	2B, 2C, 2D, 26
American crow	*Corvus brachyrhychos*	1, 2B, 2C, 2D, 11, 15, 19, 20, 21, 22, 23, 24, 25, 26
Great blue heron	*Ardea herodias*	22, 25
Song sparrow	*Melospiza melodia*	2B, 2C, 15
Northern flicker	*Colaptes auratus*	15
Downy woodpecker	*Picoides pubescens*	1, 11
Canada goose	*Branta canadensis*	22
Laughing gull	*Larus atricilla*	2B, 2C, 2D, 2E, 19, 20, 21, 23, 24, 26
Mourning dove	*Zenaida macroura*	21, 23, 24
Blue jay	*Cyanocitta cristata*	1, 2B, 2C, 11, 15, 19, 20, 21, 22, 23, 24, 25, 26
Tufted titmouse	*Parus bicolor*	15
Carolina wren	*Thryothorus ludovicianus*	1, 11, 15
Sanderling	*Calidris alba*	16
Gray catbird	*Dumetella carolinensis*	1, 2B, 2C, 11, 15, 19, 20, 21, 22, 23, 24, 25, 26
Northern mockingbird	*Mimus polyglottus*	2C
Ovenbird	*Seiurus aurocarpillus*	1, 11, 15
House sparrow	*Passer domesticus*	15
Common grackle	*Quiscalus quiscila*	2B, 2C, 15
Turkey vulture	*Cathartes aura*	22, 25
Red-tail hawk	*Buteo jamaicensis*	22, 25
Belted kingfisher	*Megaceryle alcyon*	25

Table A-2
WILDLIFE OBSERVATIONS*
NAS OCEANA
December 1992

Common Name	*Scientific Name*	Location Observed
Northern bobwhite	*Corlinus virginianus*	2B
European starling	*Sturnus vulgaris*	19, 20, 21, 23, 24, 26
White-throated sparrow	*Zonotrichia albicollis*	1, 11
Black-capped chickadee	*Parus atricapillus*	1, 11, 15
Osprey	*Pandion haliaetus*	22
Ring-necked duck	*Aythya collaris*	25
American kestral	*Falco sparverius*	22
Rufous-sided towhee	*Pipilo erythrophthalmus*	1, 11
Fish		
Bluegill	*Lepomis macrochirus*	22, 25
Large-mouth bass	*Micropterus salmoides*	22, 25
Mudminnow	*Umbra pygmaea*	1, 2B, 11, 22, 25
Mosquito fish	*Gambusia affinis*	1, 2B, 11, 22, 25

*''Observations'' include direct observations and signs of the listed species.

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- Soil survey of the City of Virginia Beach (SCS, 1985)

- USGS topographic maps of NAS Oceana

These documents were reviewed for: (1) the locations of onsite wetlands, woodland areas, disturbed areas, ditches, streams, ponded areas, and other potential habitats; (2) reported plant and animal species; (3) potential archeological or historical sites; and (4) verification of existing conditions.

The Virginia Department of Natural Heritage conducted a rare, threatened, and endangered plant and animal species inventory in 1989 (DNH, 1990). Lists of rare plant and animal species known to occur near Virginia Beach and Chesapeake are included in this appendix.

Field Study Procedures

The ecological study was initiated by locating the sites and defining the boundaries for each of the study areas. The study areas generally included areas downstream of the site. Typically, the study areas were bounded by ditches, roads, or ridges. The study areas encompassed as much area as necessary to effectively characterize the ecology of the sites and surrounding environment potentially affected by activities at each site. The appropriate extent of the study area was determined by reviewing the available environmental documents, and by briefly walking or driving around the site to develop an understanding of the habitat types surrounding the site. Because of their proximity and potential for ecological interrelation, the 17 RFI sites were grouped as follows:

- Sites 1 and 11
- Sites 2B, 2C, 2D, 2E, 18, and 26
- Site 15
- Sites 19 and 20
- Sites 16, 21, 23, and 24
- Site 22
- Site 25

The ecological study qualitatively assessed the potential environmental receptors, including plant species, wetlands, and terrestrial and aquatic organisms in each study area. The sites were studied by traversing the areas on foot. Vegetation and wildlife observed, including birds, mammals, herpetofauna (amphibians and reptiles), and fish, were identified to species level when possible. In addition, wetlands, water bodies, and areas with signs of vegetative stress were described. Wetlands described were areas showing characteristic signs of inundation or saturation, including the presence of hydrophytic vegetation and surface hydrology (e.g., standing water, water-stained leaf litter, and silt deposits). Low topographic position of the area also was considered when determining if the area was a potential wetland.

Sites 2C, 2D, 2E, 16, 18, 19, 20, 21, 23, 24, and 26 are relatively small study areas with very little suitable wildlife habitat because they are in developed areas of the base where lawns, buildings, and paved areas dominate the landscape or are surrounded by development. The most developed sites, 2D, 2E, 16, 18, 21, 23, and 24, were assessed for potential receptors quickly because of the lack of natural environment in the surrounding area. Sites 2C, 19, 20, and 26 are slightly larger than the other developed sites and have adequate habitat for wildlife species adapted to living in developed areas, but the sites are completely surrounded by heavily developed areas. These areas were studied by first driving through and around the study area. The areas were then traversed on foot to characterize potential receptors that may not have been obvious from an automobile.

The transect approach was used in the larger study areas in less-developed parts of the base. Large study areas were defined for Sites 1, 2B, 11, 15, 22, and 25 because the sites are almost entirely undeveloped, or are in or near areas of important wildlife and aquatic habitat. These sites were studied by walking along transects spaced evenly across the study area. This method was used to describe the ecological characteristics of the site more thoroughly without missing less obvious indicators of potential receptors, such as wildlife signs, bird nesting sites, and small pockets of wetland habitat.

Aquatic habitat exists near Sites 1, 2B, 22, and 25. The aquatic habitat was most often characterized as ditches with intermittent to permanent flow, temporarily ponded depressions, or excavated ponds. During the ecological study, water bodies were described on the basis of visual characteristics, which included the presence of aquatic species, width, depth, flow, water clarity, signs of stress (e.g., presence of algal mats, iron precipitate, or oily sheen), and habitat suitability.

Comparison Ditch

An uncontaminated ditch upstream of SWMU 22 was studied as a basis for comparing ditches at SWMUs 1, 2B, and 22. The ditch is north of the paved access road, northwest of SWMU 22. It is near the flight line and flows toward the runway. This ditch was chosen for comparison because it appears to be healthy and unaffected by contamination and provides physical habitat comparable to Sites 1, 2B, and 22.

The ditch had no iron precipitate and had emergent vegetation growing in shallow low-flow areas and along most of the bank. In contrast, the ditches at SWMUs 1 and 2B appeared to have poor water quality as reflected by the presence of iron precipitate, petroleum-like odors, and oily sheens in some areas, and a lack of vegetation growing in any part of the submerged areas of the ditch. The ditch used for comparison had a sand/gravel substrate, and vegetation was observed along much of the bank. The dominant vegetation in the ditch included soft rush (*Juncus effusus*), sedge (*Carex* spp.), smartweed (*Polygonum* spp.), and willow (*Salix nigra*). The water in the ditch appeared clear, and no odor or oily sheen could be detected. No fish were observed in the ditch. However, except for being approximately 2 to 3 inches deep, the ditch appears to have suitable habitat for several of the same species observed in SWMU 1, 2B, and 22 ditches.

The following tables indicate the potential environmental receptors on the site, including plants and animals that were identified during the ecological study (Tables A-1 and A-2). Because the study was conducted in late fall, many indigenous migrating or hibernating species were not observed. For this reason, lists of plant and animal species known to occur at or near Oceana are provided in Tables A-3 and A-4. Rare plants and animals that may exist in the area are listed in Tables A-5 and A-6.

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Table A-3

List of Common Plants Likely to Occur on NAS Oceana

Trees

*	Loblolly Pine (Pinus taeda)
	Pond Pine (Pinus serotina)
	Bald Cypress (Taxodium distichum)
*	Atlantic White Cedar (Chamaecyparis thyoides)
*	Red Cedar (Juniperus virginiana)
*	Black Willow (Salix nigra)
	Swamp Cottonwood (Populus heterophylla)
*	Hop Hornbeam (Ostrva virginiana)
*	Musclewood (Carpinus caroliniana)
*	American Beech (Fagus grandifolia)
	White Oak (Quercus alba)
	Overcup Oak (Quercus lyrata)
*	Swamp Chestnut Oak (Quercus michauxii)
*	Southern Red Oak (Quercus falcata)
*	Cherrybark Oak (Quercus falcata var. pagodaefloia)
	Water Oak (Quercus nigra)
*	Willow Oak (Quercus phellos)
*	Laurel Oak (Quercus laurifolia)
	Post Oak (Quercus stellata)
*	Black Oak (Quercus velutina)
*	Yellow Poplar (Liriodendron tulipifera)
*	Sweetbay (Magnolia virginiana)
*	Pawpaw (Asimina triloba)
	Redbay (Persea borbonia)
	Sassafras (Sassafras albidum)
*	Sweetgum (Liquidambar styraciflua)
	American Sycamore (Platanus occidentalis)
	Washington Thorn (Crataegus phaenopyrum)
	Shadbush (Amelanchier canadensis)
*	American Holly (Ilex opaca)
	Box Elder (Acer negundo)
*	Red Maple (Acer rubrum)
	Silky Camellia (Scewartia malacodendron)
*	Black Gum (Nyssa sylvatica)
	Tupelo Gum (Nyssa aquatica)
	Dogwood (Cornus florida)
	Sourwood (Oxydendrum arboreum)

* Species observed at NAS Oceana during ecological assessment in 1992.

Table A-3
List of Common Plants Likely to Occur on NAS Oceana (continued)

Persimmon (Diospyros virginiana)
Horse Sugar (Symplocos tinctoria)
Carolina Ash (Fraxinus caroliniana)
Green Ash (Fraxinus pennsylvanica)
Pumpkin Ash (Fraxinus tomentosa)
* Black Cherry (Prunus serotina)

Shrubs

* Wax Myrtle (Myrica cerifera)
Tag Alder (Alnus serrulata)
Virginia Willow (Itea virginica)
Swamp Rose (Rosa palustris)
Red Chokeberry (Sorbus arbutifolia)
Wild Azalea (Rhododendron nudiflorum)
Swamp Azalea (Rhododendron viscosum)
Sheep Laurel (Kalmia angustifolia)
Male-Berry (Lyonia lingustrina)
Fetter-Bush (Lyonia lucida)
Dog-Hobble (Leucothoe axillaris)
Fetter-Bush (Leucothoe racemosa)
Poison Sumac (Toxicodenron vernix)
* Winged Sumac (Rhus copallina)
Winterberry (Ilex verticillata)
Inkberry (Ilex glabra)
Sweet Gallberry (Ilex coriacea)
Strawberry Bush (Euonymus americanus)
* Devil's Walking Stick (Aralia spinosa)
Sweet Pepperbush (Clethra alnifolia)
* Righbush Blueberry (Vaccinium corymbosum)
French Mulberry (Callicarpa americana)
Possumhaw Virburnum (Viburnum nudum)
* Elderberry (Sambucus canadensis)
Titi (Cyrilla racemiflora)
* Groundsel-Tree (Baccharis halmifolia)

* Species observed at NAS Oceana during ecological assessment in 1992.

Table A-3
List of Common Plants Likely to Occur on NAS Oceana (continued)

Vines

Greenbrier (Smilax hispida)
* Greenbrier (Smilax rotundifolia)
Greenbrier (Sawbrier) (Smilax glauca)
Greenbrier (Coral Greenbrier) (Smilax walteri)
Greenbrier (Smilax laurifolia)
Wild Yac (Dioscorea villosa)
Leather-Flower (Clematis crispa)
Climbing Hydrangea (Decumaria barbara)
* Poison Ivy (Toxicodendron radicans)
Rattan Vine (Berchemia scandens)
Virginia Creeper (Parthenocissus quinquefolia)
Muscadine Grape (Vitis rotundifolia)
Fox Grape (Vitis labrusca)
Summer Grape (Vitis aestivalis)
Maypop (Passiflora incarnata)
Yellow Jessamine (Gelsemium sempervirens)
Cross Vine (Anisostichus capreolata)
Trumpet Vine (Campsis radicans)
* Japanese Honeysuckle (Lonicera japonica)
Coral Honeysuckle (Lonicera sempervirens)
Climbing Hempweed (Mikania scandens)

Ferns and Fern Allies

Groundpine (Lycopodium obscurum)
Running-Pine (Lycopodium flabelliforme)
Royal Fern (Osmunda regalis)
Cinnamon Fern (Osmunda cinnamomea)
Climbing Fern (Lygodium palmatum)
May-scented Fern (Dennstaedtia punctilobula)
Bracken Fern (Pteridium aquilinum)
Southern Lady Fern (Athyrium asplenioides)
Log Fern (Dryopteris celsa)
Fancy Fern (Dryopteris intermedia)
New York Fern (Thelypteris noveboracensis)
Marsh Fern (Thelypteris palustris)
Sensitive Fern (Onoclea sensibilis)

* Species observed at NAS Oceana during ecological assessment in 1992.

Table A-3
List of Common Plants Likely to Occur on NAS Oceana (continued)

Netted-Chain Fern (Woodwardia areolata)
Virginia Chain Fern (Woodwardia virginica)
Ebony Spleenwort (Aeplenium platyneuron)
Resurrection Fern (Polypodium polypodioides)

Herbaceous plants

Duckweeds (Lena valdiviana)
Duckweeds (Spirodela oligorrhiza)
Dayflower (Comelina virginica)
Dwarf Trillium (Trillium pusillum)
Indian Cucumber (Medeola virginiana)
Blue Eyed Grass (Sisyrinchium angustifolium)
Pink Lady's Slipper (Cypripedium acaule)
Southern Twayblade (Listera australis)
Downy Rattlesnake Plantain (Goodyera pubescens)
Crane Fly Orchid (Tipularia discolor)
Lizard's Tail (Saururus cernuus)
* False Nettle (Boehmeria cylindrica)
Mistletoe (Phoradendron serotinum)
Jumpseed (Tovara virginiana)
* Smartweed (Polygonum hydropiperoides)
Knotweed (Polygonum pensylvanicum)
Pokeweed (Phytolacca americana)
Chickweed (Stellaria media)
Yellow Pond-Lilly (Nuphar luteum)
Leather-Flower (Clematis viorna)
Buttercups (Ranunculus species)
Bitter Cress (Cardamine hirsuta)
Mock Strawberry (Duchesnea indica)
Partridge Pea (Cassia fasciculata)
Lespedeza (Lespedeza cuneata)
Lady's Sorrel (Oxalis dillenii)
Wild Geranium (Geranium carolinianum)
Jewel-Weed (Impatiens capensis)
St. John's Wort (Hypericum hypericoides)
St. John's Wort (Hypericum mutilum)
St. John's Wort (Hypericum virginicum)
Violet (Viola primulifolia)
Water Loosestrife (Decodon verticillatus)

* Species observed at NAS Oceana during ecological assessment in 1992.

Table A-3
List of Common Plants Likely to Occur on NAS Oceana (continued)

Meadow-Beauty (Rhexia mariana)
* Water Primrose (Ludwigia alternifolia)
* Water Primrose (Ludwigia palustris)
Mermaid-Weed (Proserpinaca palustris)
Queen Anne's Lace (Daucus carota)
Marsh Pennywork (Hydrocotyle umbellata)
Heal-All (Prunella vulgaris)
Skullcap (Scutellaria integrifolia)
Nightshade (Solanum carolienense)
Gerardia (Agalinis purpurea)
Squaw-Root (Conapholis americana)
Beech-Drops (Epifagus virginiana)
Bladderwort (Utricularia gibba)
Purple Bladderwort (Utricularia purpurea)
Great Bladderwort (Utricularia inflata)
Diodia (Diodia virginiana)
Partridge Berry (Mitchella repens)
Cardinal Flower (Lobelia cardinalis)
Yarrow (Achillea millefolium)
Daisey Fleabane (Ericeron annuus)
Dog-Fennel (Eupatorium capillifolium)
Mistflower (Eupatorium coelestinum)
Joe-Pye-Weed (Eupatorium maculatum)
* Goldenrod (Solidago erecta)
Dandelion (Taraxacum officinale)
Ironweed (Vernonia noveboracensis)

Grasses-Sedges-Rushes

Cotton Grass (Eriphorum virginicum)
* Wool Grass (Scripus cyperinus)
* Foxtail Grasses (Setaria - species)
* Panic Grasses (Panicum - species)
Sedges (Cyperus - species)
* Sedges (Carex - species)
* Switch Cane (Arundinaria gigantea)
Rushes (Juncus bufonius)
Rushes (Juncus repens)

* Species observed at NAS Oceana during ecological assessment in 1992.

Table A-3
Sources

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Table A-4

Virginia Department of Game and Inland Fisheries
Fish and Wildlife Information System

Fish and Wildlife Species Known or Probable in Virginia Beach

	Common Name	Scientific Name
	FISH	
	Alewife	*Alosa pseudoharengus*
	Bass, largemouth	*Micropterus salmoides*
	Bass, smallmouth	*Micropterus dolomieui*
	Bass, striped	*Morone saxatilis*
	Bass, white	*Morone chrysops*
*	Bluegill	*Lepomis macrochirus*
	Bowfin	*Amia calva*
	Bullhead, brown	*Ameiurus nebulosus*
	Bullhead, yellow	*Ameiurus natalis*
	Carp, common	*Cyprinus carpio*
	Catfish, channel	*Ictalurus punctatus*
	Catfish, white	*Americus catus*
	Crappie, black	*Pomoxis nigromaculatus*
	Dace, rosyside	*Clinostomus funduloides*
	Gar, longnose	*Lepisosteus osseus*
	Killifish, banded	*Fundulus diaphanus*
	Killifish, marsh	*Fundulus confluentus*
	Minnow, eastern silvery	*Hybognathus regius*
*	Mosquitofish	*Gambusia affinis*
*	Mudminnow, eastern	*Umbra pygmaea*
	Perch, white	*Morone americana*
	Perch, yellow	*Perca flavescens*
	Pickerel, chain	*Esox niger*
	Pickerel, redfin	*Esox americanus americanus*
	Pumpkinseed	*Lepomis gibbosus*
	Shad, gizzard	*Dorosoma cepedianum*
	Shad, threadfin	*Dorosoma petenense*
	Shiner, golden	*Notemigonus crysoleucas*
	Sunfish, banded	*Enneacanthus obesus*
	Sunfish, bluespotted	*Enneacanthus gloriosus*
	Sunfish, mud	*Acantharchus pomotis*
	Sunfish, redear	*Lepomis microlophus*
	Walleye	*Stizostedion vitreum vitreum*
	Warmouth	*Lepomis gulosus*
	AMPHIBIANS	
	Amphiuma, two-toed	*Amphiuma means*
*	Bullfrog	*Rana catesbeiana*
*	Frog, Brimley's chorus	*Pseudacris brimleyi*
	Frog, carpenter	*Rana virgatipes*
*	Frog, green	*Rana clamitans*
	Frog, little grass	*Limnaoedus ocularis*
	Frog, pickerel	*Rana palustris*
	Frog, southern cricket	*Acris gryllus gryllus*
*	Frog, southern leopard	*Rana utricularia*
	Frog, upland chorus	*Pseudacris triseriata feriarum*
	Newt, red-spotted	*Notophthalmus viridescens viridescens*
*	Peeper, northern spring	*Hyla crucifer crucifer*
*	Salamander, Coastal Plain slimy	*Plethodon chlorobryonous*
	Salamander, eastern mud	*Pseudotriton montanus montanus*
	Salamander, four-toed	*Hemidactylium scutatum*
	Salamander, many-lined	*Stereochilus marginatus*

* = Species observed at Oceana NAS during "natural heritage inventory" in 1989

Table A-4

Virginia Department of Game and Inland Fisheries
Fish and Wildlife Information System

Fish and Wildlife Species Known or Probable in Virginia Beach

	Common Name	Scientific Name
	Salamander, marbled	*Ambystoma opacum*
	Salamander, northern dusky	*Desmognathus fuscus fuscus*
	Salamander, northern two-lined	*Eurycea bislineata bislineata*
*	Salamander, redback	*Plethodon cinereus*
	Salamander, slimy	*Plethodon glutinosus glutinosus*
	Salamander, southern dusky	*Desmognathus auriculatus*
	Salamander, southern two-lined	*Eurycea bislineata cirrigera*
	Salamander, spotted	*Ambystoma maculatum*
	Salamander, three-lined	*Eurycea longicauda guttolineata*
	Siren, greater	*Siren lacertina*
	Spadefoot, eastern	*Scaphiopus holbrooki holbrooki*
	Toad, Fowler's	*Bufo woodhousii fowleri*
*	Toad, eastern narrowmouth	*Gastrophryne carolinensis*
*	Toad, southern	*Bufo terrestris*
*	Treefrog, Cope's gray	*Hyla chrysoscelis*
	Treefrog, gray	*Hyla versicolor*
	Treefrog, green	*Hyla cinerea*
*	Treefrog, pine woods	*Hyla femoralis*
*	Treefrog, squirrel	*Hyla squirrela*
	Waterdog, dwarf	*Necturus punctatus*
	REPTILES	
	Cooter, Florida	*Chrysemys floridana floridana*
	Copperhead, northern	*Agkistrodon contortrix mokason*
	Cottonmouth, eastern	*Agkistrodon piscivorus piscivorus*
	Kingsnake, eastern	*Lampropeltis getulus getulus*
	Kingsnake, scarlet	*Lampropeltis triangulum elapsoides*
	Lizard, eastern glass	*Ophisaurus ventralis*
	Lizard, eastern slender glass	*Ophisaurus attenuatus longicaudus*
*	Lizard, northern fence	*Sceloporus undulatus hyacinthinus*
*	Racer, northern black	*Coluber constrictor constrictor*
	Racerunner, six-lined	*Cnemidophorous sexlineatus*
	Rattlesnake, canebrake	*Crotalus horridus atricaudatus*
	Skink, broadhead	*Eumeces laticeps*
*	Skink, five-lined	*Eumeces fasciatus*
	Skink, ground	*Scincella lateralis*
	Skink, southeastern five-lined	*Eumeces inexpectatus*
*	Slider, yellow-bellied	*Tachemys scripta*
*	Snake, black rat	*Elaphe obsoleta obsoleta*
	Snake, brown water	*Nerodia taxispilota*
	Snake, corn	*Elaphe guttata guttata*
*	Snake, eastern earth	*Virginia valeriae*
	Snake, eastern garter	*Thamnophis sirtalis sirtalis*
	Snake, eastern hognose	*Heterodon platyrhinos*
	Snake, eastern mud	*Farancia abacura abacura*
	Snake, eastern ribbon	*Thamnophis sauritus sauritus*
*	Snake, eastern worm	*Carphophis amoenus amoenus*
	Snake, northern brown	*Storeria dekayi dekayi*
	Snake, northern red-belly	*Storeria occipitomaculata*
*	Snake, northern ringneck	*Diadophis punctatus edwardsii*
*	Snake, northern water	*Nerodia sipedon sipedon*
	Snake, rainbow	*Farancia erytrogramma erytrogramma*
	Snake, red-belly water	*Nerodia erythrogaster erythrogaster*
*	Snake, rough green	*Opheodrys aestivus*

* = Species observed at Oceana NAS during "natural heritage inventory" in 1989

Virginia Department of Game and Inland Fisheries
Fish and Wildlife Information System

Fish and Wildlife Species Known or Probable in Virginia Beach

	Common Name	Scientific Name
	Snake, scarlet	*Cemophora coccinea*
	Snake, southern ringneck	*Diadophis punctatus punctatus*
	Stinkpot	*Sternotherus odoratus*
*	Terrapin, northern diamondback	*Malaclemys terrapin terrapin*
	Turtle, Atlantic green sea	*Chelonia mydas mydas*
	Turtle, Kemp's Ridley sea	*Lepidochelys kempi*
*	Turtle, common snapping	*Chelydra serpentina serpentina*
*	Turtle, eastern box	*Terrapene carolina carolina*
	Turtle, eastern chicken	*Deirochelys reticularia reticularia*
*	Turtle, eastern mud	*Kinosternon subrubrum subrubrum*
*	Turtle, eastern painted	*Chrysemys picta picta*
	Turtle, hawksbill sea	*Eretmochelys imbricata*
	Turtle, leatherback sea	*Dermochelys coriacea coriacea*
	Turtle, loggerhead sea	*Caretta caretta caretta*
*	Turtle, red-bellied	*Pseudemys rubriventris*
	Turtle, spotted	*Clemmys guttata*
	BIRDS	
	Bittern, American	*Botaurus lentiginosus*
	Bittern, least	*Ixobrychus exilis exilis*
*	Blackbird, red-winged	*Agelaius phoeniceus*
	Bluebird, eastern	*Sialia sialis*
*	Bobwhite, northern	*Colinus virginianus*
	Bufflehead	*Bucephala albeola*
	Bunting, indigo	*Passerina cyanea*
	Bunting, lark	*Calamospiza melanocorys*
	Canvasback	*Aythya valisineria*
*	Cardinal, northern	*Cardinalis cardinalis*
*	Catbird, gray	*Dumetella carolinensis*
*	Chat, yellow-breasted	*Icteria virens virens*
*	Chickadee, Carolina	*Parus carolinensis*
	Cormorant, double-crested	*Phalacrocorax auritus floridanus*
	Cormorant, great	*Phalacrocorax carbo*
*	Cowbird, brown-headed	*Molothrus ater*
*	Crow, American	*Corvus brachyrhynchos*
*	Crow, fish	*Corvus ossifragus*
*	Cuckoo, yellow-billed	*Coccyzus americanus*
*	Dove, mourning	*Zenaida macroura carolinensis*
*	Dove, rock	*Columba livia*
	Dowitcher, long-billed	*Limnodromus scolopaceus*
	Dowitcher, short-billed	*Limnodromus griseus*
	Duck, American black	*Anas rubripes*
	Duck, ruddy	*Oxyura jamaicensis*
*	Duck, wood	*Aix sponsa*
	Egret, cattle	*Bubulcus ibis*
	Egret, great	*Casmerodius albus egretta*
	Egret, snowy	*Egretta thula*
*	Finch, house	*Carpodacus mexicanus*
*	Flicker, northern	*Colaptes auratus*
*	Flycatcher, Acadian	*Empidonax virescens*
*	Flycatcher, great crested	*Myiarchus crinitus*
	Gadwall	*Anas strepera*
	Gnatcatcher, blue-gray	*Polioptila caerulea*
	Godwit, marbled	*Limosa fedoa*

* = Species observed at Oceana NAS during "natural heritage inventory" in 1989

Virginia Department of Game and Inland Fisheries
Fish and Wildlife Information System

Fish and Wildlife Species Known or Probable in Virginia Beach

	Common Name	Scientific Name
*	Goldfinch, American	*Carduelis tristis*
	Goose, Canada	*Branta canadensis*
	Goose, greater snow	*Chen caerulescens atlanticus*
	Goose, lesser snow	*Chen caerulescens caerulescens*
	Grackle, boat-tailed	*Quiscalus major*
*	Grackle, common	*Quiscalus quiscula*
	Grebe, horned	*Podiceps auritus*
*	Grebe, pied-billed	*Podilymbus podiceps*
	Grebe, red-necked	*Podiceps grisegena*
*	Grosbeak, blue	*Guiraca caerulea caerulea*
	Gull, great black-backed	*Larus marinus*
	Gull, herring	*Larus argentatus*
*	Gull, laughing	*Larus atricilla*
*	Gull, ring-billed	*Larus delawarensis*
*	Hawk, red-shouldered	*Buteo lineatus lineatus*
	Hawk, red-tailed	*Buteo jamaicensis*
	Hawk, sharp-shinned	*Accipiter striatus velox*
	Heron, great blue	*Ardea herodias herodias*
*	Heron, green-backed	*Butorides striatus virescens*
	Heron, little blue	*Egretta caerulea caerulea*
	Heron, tricolored	*Egretta tricolor*
*	Hummingbird, ruby-throated	*Archilochus colubris*
	Ibis, glossy	*Plegadis falcinellus*
*	Jay, blue	*Cyanocitta cristata*
	Junco, dark-eyed	*Junco hyemalis*
	Kestrel, American	*Falco sparverius sparverius*
	Killdeer	*Charadrius vociferus*
*	Kingbird, eastern	*Tyrannus tyrannus*
*	Kingfisher, belted	*Ceryle alcyon*
	Kite, American swallow-tailed	*Elanoides forficatus forficatus*
	Kite, Mississippi	*Ictinia mississippiensis*
	Knot, red	*Calidris canutus rufus*
	Loon, red-throated	*Gavia stellata*
	Mallard	*Anas platyrhynchos*
*	Martin, purple	*Progne subis*
*	Meadowlark, eastern	*Sturnella magna*
	Merganser, hooded	*Lophodytes cucullatus*
	Merlin	*Falco columbarius*
*	Mockingbird, northern	*Mimus polyglottos*
	Moorhen, common	*Gallinula chloropus cachinnans*
	Night-heron, black-crowned	*Nycticorax nycticorax hoactii*
	Night-heron, yellow-crowned	*Nyctanassa violaceus violaceus*
	Nighthawk, common	*Chordeiles minor*
	Nuthatch, brown-headed	*Sitta pusilla*
	Oriole, orchard	*Icterus spurius*
*	Osprey	*Pandion haliaetus carolinensis*
*	Ovenbird	*Seiurus aurocapillus*
*	Owl, great horned	*Bubo virginianus*
	Pewee, eastern wood	*Contopus virens*
	Phoebe, eastern	*Sayornis phoebe*
	Rail, Virginia	*Rallus limicola*
	Rail, clapper	*Rallus longirostris crepitans*
	Rail, king	*Rallus elegans*
*	Robin, American	*Turdus migratorius*
	Sanderling	*Calidris alba*

* = Species observed at Oceana NAS during "natural heritage inventory" in 1989

Virginia Department of Game and Inland Fisheries
Fish and Wildlife Information System

Fish and Wildlife Species Known or Probable in Virginia Beach

	Common Name	Scientific Name
	Sandpiper, least	*Calidris minutilla*
	Sandpiper, purple	*Calidris maritima*
	Sandpiper, spotted	*Actitis macularia*
	Sandpiper, western	*Calidris mauri*
	Scaup, lesser	*Aythya affinis*
	Scoter, black	*Melanitta nigra americana*
	Scoter, surf	*Melanitta perspicillata*
	Scoter, white-winged	*Melanitta fusca deglandi*
	Screech-owl, eastern	*Otus asio*
	Shoveler, northern	*Anas clypeata*
	Skimmer, black	*Rynchops niger*
	Snipe, common	*Gallinago gallinago*
	Sparrow, chipping	*Spizella passerina*
*	Sparrow, field	*Spizella pusilla*
*	Sparrow, grasshopper	*Ammodramus sabannarum pratensis*
	Sparrow, house	*Passer domesticus*
*	Sparrow, song	*Melospiza melodia*
*	Starling, European	*Sturnus vulgaris*
*	Swallow, barn	*Hirundo rustica*
	Swallow, tree	*Tachycineta bicolor*
*	Swift, chimney	*Chaetura pelagica*
	Tanager, scarlet	*Piranga olivacea*
	Tanager, summer	*Piranga rubra*
	Teal, blue-winged	*Anas discors orphna*
	Teal, green-winged	*Anas crecca carolinensis*
	Tern, Forster's	*Sterna forsteri*
	Tern, Sandwich	*Sterna sandvicensis acuflavidus*
	Tern, common	*Sterna hirundo*
	Tern, gull-billed	*Sterna nilotica aranea*
	Tern, royal	*Sterna maxima maximus*
*	Thrasher, brown	*Toxostoma rufum*
*	Thrush, wood	*Hylocichla mustelina*
*	Titmouse, tufted	*Parus bicolor*
*	Towhee, rufous-sided	*Pipilo erythrophthalmus*
	Turnstone, ruddy	*Arenaria interpres morinella*
*	Vireo, red-eyed	*Vireo olivaceus*
	Vireo, solitary	*Vireo solitarius*
*	Vireo, white-eyed	*Vireo griseus*
	Vireo, yellow-throated	*Vireo flavifrons*
	Vulture, black	*Coragyps atratus*
*	Vulture, turkey	*Cathartes aura*
	Warbler, black-and-white	*Mniotilta varia*
	Warbler, hooded	*Wilsonia citrina*
	Warbler, northern parula	*Parula americana*
	Warbler, palm	*Dendroica palmarum*
*	Warbler, pine	*Dendroica pinus*
	Warbler, prairie	*Dendroica discolor*
	Warbler, prothonotary	*Protonotaria citrea*
*	Warbler, yellow	*Dendroica petechia*
	Warbler, yellow-rumped	*Dendroica coronata cornata*
	Warbler, yellow-throated	*Dendroica dominica*
	Waterthrush, Louisiana	*Seiurus motacilla*
*	Waxwing, cedar	*Bombycilla cedrorum*
	Wigeon, American	*Anas americana*
	Willet	*Catoptrophorus semipalmatus semipalmatus*

* = Species observed at Oceana NAS during "natural heritage inventory" in 1989

Table A-4

Virginia Department of Game and Inland Fisheries
Fish and Wildlife Information System

Fish and Wildlife Species Known or Probable in Virginia Beach

	Common Name	Scientific Name
*	Woodcock, American	*Scolopax minor*
*	Woodpecker, downy	*Picoides pubescens medianus*
*	Woodpecker, hairy	*Picoides villosus*
*	Woodpecker, pileated	*Dryocopus pileatus*
*	Woodpecker, red-bellied	*Melanerpes carolinus*
	Woodpecker, red-headed	*Melanerpes erythrocephalus*
*	Wren, Carolina	*Thryothorus ludovicianus*
	Wren, house	*Troglodytes aedon*
*	Yellowthroat, common	*Geothlypis trichas brachidactylus*
	MAMMALS	
*	Bat, big brown	*Eptesicus fuscus*
	Bat, northern yellow	*Lasiurus intermedius floridanus*
	Bat, seminole	*Lasiurus seminolus*
	Beaver	*Castor canadensis*
*	Cottontail, eastern	*Sylvilagus floridanus mallurus*
*	Deer, white-tailed	*Odocoileus virginianus*
*	Fox, gray	*Urocyon cineroeargenteus*
	Lemming, southern bog	*Synaptomys cooperi helaletes*
	Mink, common	*Mustela vison mink*
*	Mole, eastern	*Scalopus aquaticus aquaticus*
	Mouse, Pungo white-footed	*Peromyscus leucopus easti*
	Mouse, common golden	*Ochrotomys nuttalli nuttalli*
*	Mouse, common white-footed	*Peromyscus leucopus leucopus*
	Mouse, cotton	*Peromyscus gossypinus gossypinus*
	Mouse, eastern harvest	*Reithrodontomys humulus humulus*
*	Mouse, house	*Mus musculus*
*	Muskrat	*Ondatra zibethica*
*	Nutria	*Myocastor coypus*
*	Oppossum	*Didelphis virginianus*
	Otter, river	*Lutra canadensis lataxina*
	Rabbit, marsh	*Sylvilagus palustris palustris*
*	Raccoon	*Procyon lotor lotor*
*	Rat, Norway	*Rattus norvegicus*
*	Rat, marsh rice	*Oryzomys palustris palustris*
	Shrew, Dismal Swamp southeastern	*Sorex longirostris fisheri*
*	Shrew, least	*Cryptotis parva parva*
*	Shrew, short-tailed	*Blarina carolinensis*
*	Shrew, southeastern	*Sorex longirostris longirostris*
	Squirrel, black fox	*Sciurus niger niger*
*	Squirrel, eastern gray	*Scurius carolinensis*
	Squirrel, southern flying	*Glaucomys volans volans*
	Vole, common pine	*Microtus pinetorum pinetorum*
*	Vole, meadow	*Microtus pennsylvanicus*
	Weasel, long-tailed	*Mustela frenata noveboracensis*

* = Species observed at Oceana NAS during "natural heritage inventory" in 1989

Source: Virginia Department of Game and Inland Fisheries
Fish and Wildlife Information System (1992)

Table A-5

RARE PLANTS KNOWN FROM VIRGINIA BEACH AND CHESAPEAKE

<u>Aster elliotti</u>
<u>Bacopa monnieri</u>
<u>Boltonia caroliniana</u>
<u>Bulbostylis ciliatifolia</u>
<u>Cardamine longii</u>
<u>Carex reniformis</u>
<u>Carex walteriana</u>
<u>Cassia fasciculata</u>
<u>Chamaecyparis thyoides</u>
<u>Cladium jamaicense</u>
<u>Cladium mariscoides</u>
<u>Cuscuta cephalanthii</u>
<u>Cyperus haspan</u>
<u>Desmodium strictum</u>
<u>Dichromena colorata</u>
<u>Drosera intermedia</u>
<u>Eleocharis baldwinii</u>
<u>Eleocharis halophila</u>
<u>Eleocharis radicans</u>
<u>Eleocharis rostellata</u>
<u>Eleocharis vivipara</u>
<u>Erigeron vernus</u>
<u>Eupatorium recurvans</u>
<u>Euphorbia ammannioides</u>
<u>Fimbristylis caroliniana</u>
<u>Galium hispidulum</u>
<u>Heliotropium curassavicum</u>
<u>Hydrocotyle bonariensis</u>
<u>Hypoxis longii</u>
<u>Iresine rhizomatosa</u>
<u>Iva imbricatas</u>
<u>Juncus crassifolius</u>
<u>Juncus elliottii</u>
<u>Juncus megacephalus</u>
<u>Juniperus communis</u>
<u>Kalmia angustifolia</u>
<u>Lechea maritima</u>
<u>Lilaeopsis carolinensis</u>
<u>Limnobium spongia</u>
<u>Lippia nodiflora</u>
<u>Listera australis</u>
<u>Lobelia elongata</u>
<u>Ludwigia alata</u>
<u>Ludwigia Brevipes</u>
<u>Lycopodium inundatum</u>
<u>Nothoscordum bivalve</u>
<u>Nymphoides aquatica</u>
<u>Osmanthus americanus</u>
<u>Physalis viscosa</u>
<u>Physostegia leptophylla</u>
<u>Quercus hemisphaerica</u>
<u>Quercus incana</u>
<u>Quercus laevis</u>
<u>Quercus margarettae</u>
<u>Rhynchospora fascicularis</u>
<u>Scirpus acutus</u>
<u>Scirpus etuberculatus</u>
<u>Spiranthes odorata</u>
<u>Stewartia malacodendron</u>
<u>Stipulicida setacea</u>
<u>Tillandsia usneoides</u>
<u>Triglochin striatum</u>
<u>Typha domingensis</u>
<u>Utricularia fibrosa</u>
<u>Utricularia pupurea</u>
<u>Vaccinium macrocarpon</u>
<u>Verbena scabra</u>
<u>Xyris caroliniana</u>

Source: DNH, Technical Report 90-6, 1990

Table A-6

RARE ANIMAL SPECIES KNOWN FROM THE CITIES OF CHESAPEAKE AND VIRGINIA BEACH, VIRGINIA WITH THE POTENTIAL TO OCCUR ON OCEANA NAS

	Recorded from	
	Va Beach	Chesapeake
Amphibians		
Stereochilus marginatus (Many-lined salamander)	historical	
Siren lacertina (Greater Siren)	X	X
Limnaoedus ocularis (Little grass frog)	X	X
Rana virgatipes (Carpenter frog)	X	X
Reptiles		
Crotalus horridus atricaudatus (Canebrake rattlesnake)	X	X
Deirochelys reticularia (Chicken turtle)	X	
Ophisaurus ventralis (Eastern glass lizard)	X	historical
Birds		
Least Bittern	X	X
Bald Eagle	historical	
Black-crowned Night Heron	X	
Great Blue Heron	X	X
Great Egret	X	X
Hooded Merganser	X	
Pied-billed Grebe	X	
Red-cockaded Woodpecker	historical	X
Spotted Sandpiper	X	X
Swainson's Warbler		X
MAMMALS		
Condylura cristata parva (star-nosed mole)	X	X
Blarina brevicauda telmalestes (Dismal Swamp short-tailed shrew)		X
Sorex longirostris fisheri (Dismal Swamp shrew)	X	X
Synaptomys cooperi helaletes (southern bog lemming)	?	X
Plecotus rafinesquii (Rafineque's big-eared bat)	X	X
Lasiurus seminolis (Seminole bat)		X
Sylvilagus palustris (marsh rabbit)	X	X

Source: DNH, Technical Report 90-6, 1990

Ecological Assessment

Introduction

This section describes the environmental assessment component (EAC) of the health and environmental assessment (HEA) of the RFI analytical data. The EAC provides a method for assessing the potential that existing site-related contaminants may affect site-specific biota and the general environment. The elements of the EAC are: (1) the identification of receptors and potential ecological chemicals of concern (COCs) for evaluating the potential threat to the environment, and (2) an assessment of the potential exposure routes and bioavailability of the contaminants. This assessment is based on qualitative comparisons of exposure point concentrations to existing agency-promulgated ecological criteria to determine potential effects of ecological COCs to environmental receptors. Current state and federal criteria listed in the RFI guidance were used for comparisons. In addition, several other resources were used in the screening process, especially EPA guidance documents listing established environmental criteria for surface water, soil, and sediment.

The organic and inorganic chemical data are compared to federal ecological criteria in Tables A-7 through A-12. Where agency-promulgated ecological criteria were not available, eastern United States background concentrations for inorganics or proposed RCRA action limits were used. The presence of an inorganic constituent above background for the eastern United States does not necessarily indicate that the constituent poses a threat to the environment. This comparison was made to be conservative in the selection of COCs because established standards for inorganics in soils do not exist. Agency guidelines have no established criteria for many organics and inorganics. These constituents are either not listed in Tables A-7 through A-12 or they are listed but the lack of specific criteria is indicated in the individual criteria columns. Constituents that are not listed do not have known established or proposed criteria.

The assessment of potential ecological impacts is based on a qualitative review of biological conditions at each site and comparisons to published toxicity data. The biological evaluation program was conducted only at a level sufficient to evaluate visible signs of environmental stress and qualitative differences in floral and faunal conditions compared to unaffected sites. The EAC for each site is presented in the individual site sections of this report. The following sections describe the steps involved in the COC selection process, the specific assumptions for the screening process, and the potential effects of each ecological COC.

Table A-7
ORGANIC CONSTITUENTS DETECTED IN SOILS AT NAS OCEANA COMPARED AGAINST PROPOSED RCRA ACTION LEVELS (1990)
(All data in ppb)

Analyte	Site 1	Site 2B	Site 2C	Site 2E	Site 11	Site 16	Site 18	Site 19	Site 20	Site 21	Site 23	Site 24	Site 26	Proposed RCRA Action Level
Pesticides, Herbicides														
4,4'-DDE	2	NA	NA	NA	NA	26	*	NA	NA	NA	NA	NA	NA	2,000
4,4'-DDD	18	NA	NA	NA	NA	200	11	NA	NA	NA	NA	NA	NA	3,000
4,4'-DDT	3.4	NA	NA	NA	NA	200	8.6	NA	NA	NA	NA	NA	NA	2,000
Dieldrin	*	NA	NA	NA	NA	21	*	NA	NA	NA	NA	NA	NA	40
Chlordane	*	NA	NA	NA	NA	260	*	NA	NA	NA	NA	NA	NA	500
Chloropyrifos	*	NA	NA	NA	NA	1,200	*	NA	NA	NA	NA	NA	NA	ND
Dicamba	*	NA	NA	NA	NA	51	*	NA	NA	NA	NA	NA	NA	ND
Semivolatile Organic Compounds														
Napthelene	31,000	NA	NA	*	NA	NA	*	*	1,800	NA	*	4,900	43	N
2-Methylnapthalene	45,000	NA	NA	*	NA	NA	*	*	1,000	NA	*	3,300	100	N
1-Methylnapthalene	*	NA	NA	*	NA	NA	*	*	800	NA	*	3,700	48	N
Acenaphthene	*	NA	NA	35	*	NA	*	*	*	NA	*	*	*	N
Flourene	730	NA	NA	30	*	NA	*	*	*	NA	*	*	*	N
Phenantherene	640	NA	NA	110	*	NA	700	*	*	NA	*	*	*	N
Di-n-Butylphthalate	230	NA	NA	170	NA	NA	240	*	*	NA	NA	NA	NA	8,00(
bis(2-ethylhexyl)phthalate	2,800	NA	NA	43	NA	NA	1,300	*	*	NA	NA	NA	NA	50,(
Fluoranthene	470	NA	NA	100	*	NA	4,400	*	*	NA	*	*	*	N
Pyrene	370	NA	NA	120	*	NA	4,300	*	*	NA	*	320	*	N
Benzo(a)anthracene	190	NA	NA	54	*	NA	2,600	*	*	NA	*	*	*	N

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Table A-7
ORGANIC CONSTITUENTS DETECTED IN SOILS AT NAS OCEANA COMPARED AGAINST PROPOSED RCRA ACTION LEVELS (1990)
(All data in ppb)

Analyte	Site 1	Site 2B	Site 2C	Site 2E	Site 11	Site 16	Site 18	Site 19	Site 20	Site 21	Site 23	Site 24	Site 26	Proposed RCRA Action Level
Dibenzo(a,h)-anthracene	*	NA	NA	*	*	NA	670	*	*	NA	*	*	*	ND
Chrysene	290	NA	NA	75	*	NA	3,400	*	*	NA	*	6,100	*	ND
Benzo(b)fluoranthene	200	NA	NA	110	*	NA	4,900	*	*	NA	*	*	*	ND
Benzo(k)fluoranthene	220	NA	NA	110	*	NA	3,600	*	*	NA	*	*	*	ND
Benzo(a)pyrene	230	NA	NA	98	*	NA	4,800	*	*	NA	*	*	*	ND
Indeno(1,2,3-cd)-pyrene	170	NA	NA	110	*	NA	2,700	*	*	NA	*	*	*	ND
Benzo(g,h,i)perylene	130	NA	NA	73	*	NA	2,900	*	*	NA	*	860	NA	ND
Butylbenzylphthalate	*	NA	NA	*	NA	NA	270	NA	NA	NA	NA	NA	NA	20,00
Dibenzofuran	1,200	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	N
Volatile Organic Compounds														
Methylene Chloride	670	*	*	120	76	NA	9	24	*	NA	6	61	46	90,
Acetone	2,980	NA	NA	86	65	NA	*	41	94	NA	10	260	140	8,00
Carbon Disulfide	10	NA	NA	*	1	NA	*	*	4	NA	*	*	4	8,00
Trichlorofluoromethane	*	*	*	*	*	NA	*	*	1	NA	*	*	*	N
Toluene	6,800	NA	NA	2	2	NA	*	*	10	NA	*	15	5	20,00
Ethylbenzene	6,400	NA	NA	*	2	NA	*	*	42	NA	*	110	*	8,00
Xylene	44,000	NA	NA	21	6	NA	2	10	450	NA	*	490	12	200,0
2-Butanone	72	NA	NA	14	19	NA	*	*	27	NA	*	62	28	4,00
1,1-Dichloroethylene	*	*	*	*	*	NA	*	*	*	NA	*	*	5	10,

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Table A-7
ORGANIC CONSTITUENTS DETECTED IN SOILS AT NAS OCEANA COMPARED AGAINST PROPOSED RCRA ACTION LEVELS (1990)
(All data in ppb)

Analyte	Site 1	Site 2B	Site 2C	Site 2E	Site 11	Site 16	Site 18	Site 19	Site 20	Site 21	Site 23	Site 24	Site 26	Proposed RCRA Action Level
Trichloroethylene	*	*	*	*	*	NA	*	*	*	NA	*	*	4	60,000
Benzene	*	NA	NA	*	*	NA	*	*	*	NA	*	*	5	ND
Chlorobenzene	*	*	*	*	*	NA	*	*	*	NA	*	*	5	2,000,000
cis-1,2 Dichloroethylene	NA	*	68	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	ND
TPH	NA	NA	NA	607,000	325,000	NA	NA	3,720,000	38,100,000	242,000	63,800	341,000	166,000	ND
Furans														
Hexachlorinated-Dibenzo Furans	0.30	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	ND
PCB														
Aroclor-1260	14	NA	NA	NA	NA	NA	*	NA	NA	*	NA	NA	NA	9
Aroclor-1254	140	NA	NA	NA	NA	NA	*	NA	NA	*	NA	NA	NA	9

*Compound analyzed for but not detected
ND - No Data
NA - Not Analyzed

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Table A-8
INORGANIC CONSTITUENTS IN SOILS FROM ALL SITES COMPARED AGAINST BACKGROUND CONCENTRATIONS OF ELEMENTS IN SOILS OF THE EASTERN UNITED STATES (1984) AND PROPOSED RCRA (1990) ACTION LEVELS[1, 2]
(ppm)

Analyte	Site 1	Site 2E	Site 11	Site 16	Site 18	Site 19	Site 20	Site 23	Site 24	Site 26	[3]Eastern United States (Mean)	Proposed RCRA Action Levels
Aluminum	15,700	16,900	20,400	NA	8,690	NA	NA	4,030	14,700	29,700	33,000	ND
Antimony•	13.0	<4.6	4.2	NA	3.7	NA	NA	3.4	4.4	<4.6	0.520	30
Arsenic•	3.5	2.7	2.2	22	3	NA	NA	1.2	1.6	14	4.8	80
Barium	78.8	93.4	88.4	NA	33.9	NA	NA	19.8	61.1	87.4	290	4,000
Beryllium•	0.74	0.57	0.63	NA	0.29	NA	NA	0.24	0.56	1.2	0.550	0.20
Cadmium	1.3	6.6	0.70	NA	2.8	NA	NA	0.58	0.74	0.77	ND	40
Calcium	1,080	2,510	1,280	NA	2,180	NA	NA	662	1,100	1,370	3,400	ND
Chromium (total)	42	21.5	32.7	NA	30.9	NA	NA	2.7	14.2	40.8	33	400
Cobalt	4.8	3.6	3.9	NA	2.8	NA	NA	1.4	1.7	5.2	5.9	ND
Copper	70.8	58	10.8	10.8	38.7	NA	NA	1.8	6.8	15.6	13.0	ND
Iron	17,300	8,340	12,500	NA	8,820	NA	NA	2,820	3,770	24,330	14,000	ND
Lead•	138	53.9	12.8	22.1	113	86.3	242	5.7	14.6	21.1	14.0	ND
Magnesium	1,230	1,080	1,050	NA	784	NA	NA	419	825	1,980	2,100	ND
Manganese	40.1	64.5	25.6	NA	70.5	NA	NA	58.8	29.3	235	260	ND
Mercury	0.23	0.11	0.04	NA	0.13	NA	NA	0.03	0.11	0.13	0.081	20
Nickel	11.7	11.5	9.3	NA	7.7	NA	NA	2.0	2.9	13.4	11.0	2,00
Potassium	782	526	712	NA	280	NA	NA	285	512	1,860	12,000	ND
Selenium	0.87	<0.52	0.97	NA	0.59	NA	NA	0.46	1.0	0.86	0.30	ND

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Table A-8

INORGANIC CONSTITUENTS IN SOILS FROM ALL SITES COMPARED AGAINST BACKGROUND CONCENTRATIONS OF ELEMENTS IN SOILS OF THE EASTERN UNITED STATES (1984) AND PROPOSED RCRA (1990) ACTION LEVELS[1, 2]

(ppm)

Analyte	Site 1	Site 2E	Site 11	Site 16	Site 18	Site 19	Site 20	Site 23	Site 24	Site 26	[3]Eastern United States (Mean)	Proposed RCRA Action Levels
Silver	0.52	0.67	0.50	NA	0.45	NA	NA	0.42	0.53	0.56	ND	200
Sodium	409	338	374	NA	226	NA	NA	141	207	555	2,500	ND
Thallium	1.56	0.66	0.62	NA	0.53	NA	NA	0.49	0.62	0.65	ND	ND
Vanadium	52.2	22.7	32.5	NA	14.3	NA	NA	4.1	16.5	60.8	43	ND
Zinc	257	105	22.4	NA	121	NA	NA	16	31.2	36.1	40	ND
Cyanide	<0.11	NA	NA	NA	0.16	NA	NA	NA	NA	NA	ND	20,000
Tin	27.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.860	ND
Sulfide	18.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	ND	ND

*Compound analyzed for but not detected
NA - Not analyzed
ND - No data
• COC
[1]Maximum concentrations from all sample locations at each site.
[2]Sites 2C, 19, 20, and 21 were not analyzed for inorganic constituents.
[3]Shacklette and Boerngen, 1984. Element Concentrations in Soils and Other Surficial Materials of the Conterminous United States.
Some inorganics that were not detected are listed at concentrations equal to the IDL.

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Table A-9
ORGANIC CONSTITUENTS DETECTED IN SURFACE WATER COMPARED AGAINST PROPOSED RCRA ACTION LEVELS AND EPA WATER QUALITY CRITERIA[a]
(ppb)

Analyte	Site 1	Site 2B	Site 22	Site 25	Proposed RCRA Action Level	EPA Chronic Fresh Water-Quality Criteria for Aquatic Life	EPA Human Criteria for Ingestion of Water and Fish
TPH	540	NA	NA	NA	NS	NS	NS
Volatile Organic Compounds							
Methylene Chloride	13	4	4	5[b]	5	NS	NS
Carbon Disulfide	3	NA	*	*	4	NS	NS
Chloroform	2	*	*	*	NS	1,240	0.19
Xylenes	2	NA	*	*	30	NS	NS
1,1-Dichloroethane	*	1.5	*	*	NS	NS	NS
Bromodichloromethane	1 j	*	*	*	0.03	NS	NS

[a]Maximum concentrations from all sample locations at each site.
[b]Constituent also detected in the associated laboratory blank.
* Compound analyzed for but not detected.
NS No Standard
j Estimated value; measured value is less than the accurate qualitative limit.

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Table A-10
INORGANIC CONSTITUENTS IN SURFACE WATER AT NAS OCEANA
COMPARED AGAINST PROPOSED EPA RCRA ACTION LEVELS AND EPA WATER QUALITY CRITERIA
(ppb)

Analyte	Site 1	Site 22	Site 25	Proposed RCRA Action Levels	Aquatic Life Criteria	Human-Health Criteria[1]
Inorganics	Concentration	Concentration	Concentration	Concentration	Fresh Chronic	Water & Fish Ingestion
Aluminum	376	181	288	ND	ND	ND
Antimony	16.4 (IDL)	16.4 (IDL)	16.4 (IDL)	10	1,600*	146
Arsenic •	4.4	1.1	1.2	50	190**	0.0022
Barium	27.2	36.3	38.5	ND	ND	1,000
Beryllium •	0.26 (IDL)	0.26 (IDL)	0.26 (IDL)	0.008	5.3*	0.0037
Cadmium ••	2.8 (IDL)	2.8 (IDL)	2.8 (IDL)	10	1.1+	10
Calcium	7,510	9,170	37,100	ND	ND	ND
Chromium (Total)	2.8 (IDL)	2.8 (IDL)	2.8 (IDL)	ND	210#+	170,000#
Cobalt	3.9	3.4	2.6 (IDL)	ND	ND	ND
Copper	1.2 (IDL)	1.2 (IDL)	2.9	ND	12+	ND
Iron •	2,760	1,250	399	ND	1,000	300
Lead	1.7 (IDL)	1.7 (IDL)	1.7 (IDL)	50	3.2+	50
Magnesium	5,920	5,520	6,500	ND	ND	ND
Manganese •	114	102	29.7	ND	ND	50
Mercury ••	0.07 (IDL)	0.07 (IDL)	0.07 (IDL)	2	0.012	0.144
Nickel	11.1	9.4	13.7	700	160+	13.4

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Table A-10
INORGANIC CONSTITUENTS IN SURFACE WATER AT NAS OCEANA
COMPARED AGAINST PROPOSED EPA RCRA ACTION LEVELS AND EPA WATER QUALITY CRITERIA
(ppb)

Analyte	Site 1	Site 22	Site 25	Proposed RCRA Action Levels	Aquatic Life Criteria	Human-Health Criteria[1]
Inorganics	**Concentration**	**Concentration**	**Concentration**	**Concentration**	**Fresh Chronic**	**Water & Fish Ingestion**
Potassium	934	1,920	10,600	ND	ND	ND
Selenium	1.8 (IDL)	1.8 (IDL)	1.8 (IDL)	ND	5	10
Silver	2.0(IDL)	2.0 (IDL)	2.0 (IDL)	50	ND	50
Sodium	14,200	9,200	26,200	ND	ND	ND
Thallium	2.3 (IDL)	2.3 (IDL)	2.3 (IDL)	ND	40*	13
Vanadium	2.6 (IDL)	2.6 (IDL)	2.6 (IDL)	ND	ND	ND
Zinc	32.5	15.9	15.7	ND	110+	ND

Notes:

[1] Quality Criteria for Water (EPA, 1987), Human Health Criteria for Ingestion of Water & Fish (EPA, 1987), and Water Quality Criteria Summary (EPA, 1993) were used to screen potential COCs that may affect terrestrial organisms that ingest surface water, assuming the criteria may be slightly higher for humans because of greater biomass and metabolic differences.

IDL = Instrument detection limit.
• COC
•• Aquatic life criteria less than IDL.
* Value presented is lowest observed effect level (LOEL). Insufficient data to develop criteria.
+ Hardness dependent criterion (100 mg/l $CaCO_3$ used)
ND No Data
Trivalent chromium standards used for total chromium analysis
** Criteria based on trivalent arsenic. There is no standard for elemental arsenic.

Table A-11
'ORGANIC CONSTITUENTS IN SEDIMENTS AT NAS, OCEANA COMPARED TO EXISTING PROPOSED EPA SEDIMENT CRITERIA AND NOAA SEDIMENT GUIDELINES
(All concentrations in ppb or μg/kg unless otherwise indicated)

Analyte	Site 1	Site 2B	Site 22	Site 25	Proposed Sediment Criteria for the Protection of Benthic Organisms[1]	Proposed Sediment Criteria at 1% Organic Carbon Content[f]	NOAA ER-M Sediment Guidelines[2]
Fluoranthene	400	13,000	*	120	≤1,020 μg/g organic carbon	11,020	3,600
Dieldrin	*	*	0.56	56	≤9.0 μg/g organic carbon	90	8
Acenaphthene	*	350	*	*	≤140 μg/g organic carbon	1,400	650
Phenanthrene	*	7,400	*	93	≤120 μg/g organic carbon	1,200	1,380
DDT	*	*	1.7	25	NS	NS	7
DDE	*	*	1.4	27	NS	NS	15
Anthracene	*	2,200	*	*	NS	NS	960
Benzo(a)anthra-cene	*	6,000	*	75 J	NS	NS	1,600
Benzo(a)pyrene	*	6,400	*	*	NS	NS	2,500
Chrysene	*	7,900	*	120 J	NS	NS	2,800
Fluorene	*	320	*	*	NS	NS	640

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Table A-11
'ORGANIC CONSTITUENTS IN SEDIMENTS AT NAS, OCEANA COMPARED TO EXISTING PROPOSED EPA SEDIMENT CRITERIA AND NOAA SEDIMENT GUIDELINES
(All concentrations in ppb or μg/kg unless otherwise indicated)

Analyte	Site 1	Site 2B	Site 22	Site 25	Proposed Sediment Criteria for the Protection of Benthic Organisms[1]	Proposed Sediment Criteria at 1% Organic Carbon Content[f]	NOAA ER-M Sediment Guidelines[2]
2-Methylnaptha-lene	*	420	*	*	NS	NS	670
Pyrene	400	11,000	*	110	NS	NS	2,200

Notes:
[1]EPA, 1991
[2]National Oceanic and Atmospheric Administration (NOAA) (Long and Morgan, 1991)
* Compound analyzed for but not detected.
[a] Maximum concentrations from all sampling locations at each site.
[f] The proposed sediment criteria are based on percent organic carbon, which was not analyzed in sediments. This column is based on an assumed percent organic carbon of 1 percent.
NS - No Standard

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Table A-12
MAXIMUM CONCENTRATIONS OF INORGANIC CONSTITUENTS IN SEDIMENT COMPARED TO EXISTING SEDIMENT GUIDELINES
(All values in ppm)

Compound	Site 1	Site 22	Site 25	NOAA ER-M Sediment Guidelines[a]
Antimony	4.8	4.0[n]	4.5	25
Arsenic	2.3[b]	1.8[b]	1.0[b]	85
Cadmium	0.81	0.67	1.3	9
Chromium	3.5	6.2	6.0	145
Copper	2.5[b]	1.8[bn+]	746	390
Lead	2.3	5.5[n]	7.2[+]	110
Mercury	0.05[b]	0.05[b]	0.07	1.3
Nickel	3.6[b]	2.3	4.7	50
Silver	0.58	0.48	.47	2.2
Zinc	15.3	6.8[+]	723	270

Notes:
[a]NOAA, Long and Morgan, 1991.
[b]The reported value was less than the CDRL, but greater than or equal to the IDL.
[+]Duplicate analysis not within control limits.
[n]Spiked sample recovery not within control limits.

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Selecting Potential Ecological Chemicals of Concern

Ecological COCs are potential contaminants that can cause environmental effects at certain concentrations. Ecological COCs are not necessarily the same as the human-health criteria. Some chemicals that are relatively harmful to humans are less harmful to animals, and vice-versa.

A list of chemicals that were analyzed in soil, sediment, and surface water is found in Tables A-7 through A-12. Table A-7 compares all organic compounds detected in soil during the RFI to proposed RCRA action levels. Table A-8 compares the concentrations of all inorganic constituents to proposed RCRA action levels and literature values for mean concentrations of inorganics in soils in the eastern United States (Shacklette and Boerngen, 1984). Tables A-9 and A-10 compare surface water concentrations of organics and inorganics. Table A-9 compares organics detected in surface water during the RFI to (1) proposed RCRA action levels, (2) chronic water quality criteria for aquatic life in fresh water, and (3) human-health criteria for ingestion of water and fish. Table A-10 compares all analyzed inorganics to these same criteria. Table A-11 compares organics detected in sediments to existing proposed sediment criteria and guidelines for the protection of benthic organisms. There are no existing or proposed EPA criteria for other organics in sediment. Table A-12 compares sediment concentrations to available guidelines for inorganics.

The detected chemicals, listed in Tables A-7 through A-12, were considered as potential COCs. A screening process was used to determine which chemicals present in the areas of study might be harmful to potentially exposed ecological organisms. The observed minimum and maximum concentration of each chemical detected was screened against a variety of established criteria (as well as background concentrations for inorganic chemicals found in soil) to determine the potential for environmental effect. Many chemicals were not found at concentrations that would affect exposed organisms, based on site-specific contaminant concentrations that did not exceed established criteria. If the maximum concentration exceeded any of these criteria or guidelines, the chemical was retained as a potential COC.

Direct comparison of observed maximum concentrations of COCs in surface water to federal ambient water-quality criteria (EPA, 1987) provides an assessment of the potential threat to aquatic organisms. However, criteria for protecting terrestrial organisms from soil and surface water chemicals, as well as criteria for the protecting aquatic organisms from chemicals in sediment are not well-established. Proposed sediment criteria for four organic compounds was obtained from available agency-derived information (EPA, 1991). Guideline concentrations for 13 organics and 10 inorganics from a National Oceanographic and Atmospheric Administration (NOAA) compilation study also were used (Long and Morgan, 1991).

The absence of defensible sediment-quality criteria for other subject chemicals makes it difficult to accurately assess the extent of ecological effects to contaminated sediments. EPA is drafting sediment criteria for protecting benthic organisms for several other organic compounds. However, the current criteria for the four organic compounds, as well as future sediment criteria developed by using the same approach have an uncertainty associated with them because they are intended to protect only the most sensitive species (personal communication, Zarba, EPA, 1993). For these reasons, sediment contamination was not addressed from an ecological standpoint except where established criteria or guidelines were available to screen potential COCs.

Soil criteria were based on the conservative assumption that inorganic chemical concentrations above background in the eastern United States are potential COCs (Shacklette and Boerngen, 1984). Surface-water criteria for terrestrial organisms were taken from EPA water-quality criteria (EPA, 1987) for human exposure to water and fish through ingestion. The assumption was that the bioavailability of the COCs is the same for terrestrial organisms and humans, taking into consideration that humans may have greater biomass than potential wildlife receptors. However, some chemicals that affect humans may affect terrestrial organisms.

Potential Exposure Pathways

The potential for terrestrial plant and wildlife receptors to contact onsite contaminants in various ways is based on habitat type, feeding mechanisms, and medium. Terrestrial species can uptake contaminants via inhalation; dermal contact with soil, water, or sediments; ingestion of the medium in which the contaminant occurs; and ingestion of contaminated organisms, i.e., bioaccumulation. Aquatic organisms, benthic and pelagic, are in constant contact with the medium in which the contaminant occurs. Therefore, aquatic organisms are exposed continually via respiration, ingestion, and dermal contact. In addition, the bioconcentration of contaminants in the tissues of aquatic plant and animal species may expose aquatic and terrestrial species higher in the food chain to these same contaminants.

Bioaccumulation studies were not conducted for the EA. However, the assumption is that certain chemicals, regardless of initial concentration in the environment, are capable of accumulating through the food chain. Indirect exposure to consumer organisms, i.e., herbivores, carnivores, and omnivores, is addressed, where applicable, in the COC descriptions in this appendix.

The following sections explain the steps involved with the COC selection process and the specific assumptions for each screening process. The COC selection process compares background and compares effect levels.

Comparison to Background

A step in the selection process of ecological COCs included a comparison, shown in Table A-8, of the observed site-specific maximum concentration of inorganic elements in soil to the background concentration of that element in soils of the eastern United States (Shacklette and Boerngen, 1984). If the maximum concentration was greater than the background level, the chemical was retained as a potential ecological COC. Many inorganic chemicals occur naturally, and may not be of concern because they are ubiquitous. Naturally occurring elements such as calcium, magnesium, potassium, and sodium have low toxicities to terrestrial and aquatic organisms and act as macronutrients for natural systems. For these reasons, these elements were not assessed as potential COCs. Other common inorganics, such as iron and aluminum, that can be toxic at high concentrations were included as potential ecological COCs.

Comparison to Effect Levels

Applicable ambient water-quality criteria and standards have been derived by federal and state regulatory agencies, and are considered to be protective of most environmental aquatic receptors. Current established criteria and standards include the EPA ambient water-quality criteria for the protection of aquatic life (EPA, 1987). The exposure of terrestrial organisms to surface water was assumed to be through ingestion of water and fish. Therefore, the EPA ambient water-quality criteria for protecting human health were used to screen for COCs for terrestrial organisms with the assumption that ingestion rates and amounts are the same and that biomass may be different for terrestrial organisms and humans.

Where agency-promulgated standards or criteria were not available for surface water or soils, proposed RCRA action levels, as established by EPA (40 CFR Part 264.521), were used for screening purposes. Action levels are health- and environmental-based levels determined by EPA to be indicators for protecting human health and the environment. Where a maximum concentration exceeded the action level, the chemical was retained as a COC.

Sediment criteria or guidelines were available for certain organic chemicals, and are shown in Table A-11. Agency-promulgated sediment criteria have been proposed for four organic compounds but no criteria are available for other organics or for inorganic constituents.

However, guideline concentrations for several organics and inorganics in sediment were obtained for screening purposes from a NOAA study that compiled toxicological results from approximately 85 reports as part of the National Status and Trends (NS&T) Program (Long and Morgan, 1991). The study was used by NOAA to rank the sites in the NS&T program on the basis of the severity of contamination and was not intended as a source of criteria or standards. The procedure used in Long and Morgan was to rank concentrations within its toxicological database from lowest to highest regardless of whether the concentration affected the environment. The 10th and 50th percentile were then chosen arbitrarily as the database benchmarks "ER-L" and "ER-M." Because toxicity is a complex function of several factors rather than concentration alone, concentrations above the ER-M were found to be nontoxic during some studies and concentrations between the

ER-L and the ER-M also were commonly nontoxic. The guideline value ER-M was used for a screening comparison to concentrations detected in sediment at Oceana because: (1) the degree of confidence in the ER-L and ER-M values for polycyclic aromatic hydrocarbons (PAHs) and pesticides was said to be low (Long and Morgan, 1991); (2) most of the NOAA study sites were of brackish marine or estuarine environments and are, therefore, not strictly comparable; and (3) ER-M concentrations were closer to the four existing sediment criteria for organic compounds proposed by the EPA (EPA, 1991).

Terrestrial Organisms

Terrestrial organisms can tolerate certain concentrations of various chemicals. Terrestrial animals (birds and small mammals) ingest or come in contact with soil during feeding, grooming, and burrowing. For this report, the concentration of the chemical detected is assumed to be 100 percent bioavailable.

Terrestrial Organisms via Water Exposure

Terrestrial organisms ingest surface water directly to meet dietary requirements or obtain water by ingesting aquatic organisms. To be conservative, the assumption was that terrestrial animals would ingest surface water directly in their diet. Observed maximum concentrations were compared to EPA water-quality criteria for human health for exposure to chemical concentrations through surface water ingestion on the basis that human and terrestrial animals intake rates and amounts are the same. For this report, the amount of chemical detected is assumed to be 100 percent bioavailable.

Aquatic Organisms via Sediment Exposure

Agency-promulgated sediment criteria are not available for inorganic and most organic chemicals; however, proposed sediment criteria have been established for four organic compounds. In addition, guideline concentrations are available for preliminary screening of site concentrations for 9 other organics and 10 inorganics. Chemical concentrations in the interstitial water in the sediment are assumed to be similar to the chemical concentrations in the water column and may adversely affect benthic organisms in a way similar to pelagic species (personal communication, Zarba, EPA 1993). Therefore, water quality criteria for protecting water column aquatic species also should protect benthic infaunal species. However, these criteria were not used to screen for potential sediment COCs because of the binding potential of the chemicals to the sediment particles and the volume of interstitial water in the sediments is unknown. For screening for potential COCs, 100 percent of the detected chemical concentration in the sediment pore space was assumed to be available to organisms.

Aquatic Organisms via Water Exposure

Aquatic organisms (fish and macroinvertebrates) can become exposed to water-borne chemicals through a variety of routes. Fish and invertebrates can become exposed through integument, gill surfaces, and ingestion. Most aquatic organisms have a protective integument layer, thereby limiting exposure to potentially toxic chemicals through this route. Exposure through gill surfaces and ingestion have been documented as the most significant exposure routes for fish (Rand and Petrocelli, 1985). Fish are inescapably immersed in their aquatic media, and therefore are subjected to acute and potentially chronic exposures. The exposure risk to an aquatic organism is a function of the bioavailability of the chemical within the medium. For this report, the assumption was that the detected chemical concentration in the surface water is 100 percent bioavailable to aquatic organisms.

Chemicals of Concern

By comparing site-specific contaminant concentrations to existing ecological toxicity criteria, several chemicals were identified that are of potential concern to fish and wildlife resources at NAS Oceana. The chemicals are antimony, arsenic, beryllium, cadmium, copper, DDT, DDE, dieldrin, iron, lead, manganese, mercury, PAHs, and zinc. The following section summarizes available information on the potential impacts of each of these constituents on fish and wildlife. For each constituent, the concentrations observed during this investigation are compared to known or potential effects levels. Several of the COCs are included here because the assumptions are conservative and not necessarily because the COCs pose a threat at NAS Oceana. For example, cadmium, and mercury were not detected in surface water but are included because the standard instrument detection limit is above one or more aquatic criteria. Refer to the conservative assumptions used in selecting COCs described above.

Antimony

The database for effects of antimony to freshwater organisms is small and may indicate that plants are more affected than animals. For *Daphnia magna*, 64-hour and 48-hour EC50 values of 19,800 ppb and 530,000 ppb, respectively have been reported for antimony trichloride. EC is the effect concentration, and EC50 is the concentration that produces adverse effects to 50 percent of the test organisms.

Antimony was detected at a maximum concentration of 13,000 ppb in soil at Site 1, which exceeds eastern United States background concentrations (520 ppb) but not RCRA action levels (30,000 ppb). Antimony was not detected in surface water.

Arsenic

It is not clear from available reference literature what the effects of arsenic in soils are on wildlife. However, it has been indicated by EPA (EPA, 1987) that arsenic is not bioconcentrated to a high degree, but lower forms of aquatic life (e.g., benthic invertebrates) may accumulate higher concentrations than fish. The low bioconcentration, and short half-life of arsenic suggests that it should not produce severe effects to predators of aquatic life. However, arsenic is a carcinogen, and can cause severe reproductive and other physiological effects. Several aquatic species were shown to be affected by concentrations of 19 to 48 ppb in water (Eisler, 1988).

The maximum concentration of arsenic detected in onsite soils was 22,000 ppb, which exceeds eastern United States background concentrations (4,800 ppb), but not RCRA action levels (80,000 ppb). Arsenic was detected in onsite surface water at a maximum concentration of 4.4 ppb, which exceeds human-health criteria for the ingestion of contaminated water and fish (0.0022 ppb), but not water quality criteria for the protection of aquatic organisms (190 ppb) or proposed RCRA action levels (50 ppb). Human-health criteria, in this case, were used to screen for COCs because no standards for terrestrial organisms exist.

Beryllium

Beryllium, ingested or inhaled through soils, may produce pulmonary and skin effects. It has caused tumors in rats in laboratory tests (Amdur, *et al.*, 1991). Beryllium is a carcinogen to certain terrestrial species and man (EPA, 1980). The available data for beryllium indicates that in water acute and chronic toxicity to freshwater aquatic life occurs at concentrations as low as 130 and 5.3 ppb, respectively (EPA, 1987). More sensitive species may be affected at lower concentrations. The freshwater criterion for beryllium to protect aquatic life is dependent on water hardness (EPA, 1980).

Beryllium was detected on the site in soils at maximum concentrations of 240 ppb. Beryllium was not detected in surface water above the instrument detection level (IDL) of 0.26 ppb; however, to be conservative, the beryllium concentration in surface water is assumed to be equal to the IDL. The RCRA action level for beryllium is 200 ppb for soils and 0.008 for water, and the water quality criterion for ingesting water and fish is 0.0037 ppb for protection of human health. Human-health criteria, in this case, were used to screen COCs despite the assumption that the value may be conservative as applied to terrestrial organisms that may ingest water or fish, primarily because of differences in biomass and metabolism. Beryllium was found above potentially applicable RCRA action levels in soil samples at all of the 17 sites where it was analyzed but few soil concentrations were above the mean background concentration of beryllium in the eastern United States of 550 ppb or 0.550 ppm. The natural occurrence of beryllium at NAS Oceana at concentrations above RCRA action levels and, in some cases, somewhat higher than mean concentrations for the eastern United States is suspected but has not been confirmed by background soil sampling on the station itself.

Cadmium

Possible effects from absorption or ingestion of silver or cadmium by aquatic organisms may affect growth and reproduction (EPA, 1987). Cadmium is a known carcinogen, a probable mutagen, and may severely affect fish and wildlife (Eisler, 1988). Freshwater biota is the most sensitive group. Cadmium concentrations of 0.8 to 9.9 ppb were lethal to several aquatic insects, crustaceans, and teleosts. Concentrations of 0.7 to 5.0 ppb were associated with sublethal effects such as decreased growth, inhibited reproduction, and population alteration (Eisler, 1988). Freshwater organisms may accumulate measurable amounts of cadmium from water not considered hazardous to human health (concentrations of 0.02 to 10 ppb) (Eisler, 1988).

Cadmium was not detected in surface water above the IDL of 2.8 ppb; however, to be conservative, the concentration of cadmium is assumed to be equal to the IDL, which slightly exceeds the EPA surface-water-quality criterion of 1.1 ppb. Cadmium was detected in soils at a maximum concentration of 6,600 ppb during the RFI.

Copper

Chronic values for 15 freshwater species range from 3.873 ppb for brook trout to 60.36 ppb for northern pike. Fish, invertebrates, and freshwater plants seem to be about equally sensitive to the chronic toxicity of copper. Protection of animal species appears to offer adequate protection of most plants. Copper does not appear to bioaccumulate in the edible portion of freshwater aquatic species (EPA, 1986).

Copper was detected in sediments at Site 25 at a maximum concentration of 746,000 ppb, which exceeds the NOAA (ER-M) guideline of 390,000 ppb. Copper concentrations in sediment were a maximum of 2,500 ppb at Site 1 and 1,800 ppb at Site 2B. Copper was not analyzed in sediments at other sites. The maximum concentrations of copper in soils was 70,800 ppb at Site 1, which is above the mean background concentration of 13,000 ppb in the eastern United States. Maximum soil concentrations also were above the background mean at Sites 2E, 18, and 26. The maximum concentration of copper in surface water was 2.9 ppb.

DDT and Its Metabolite DDE

Because DDD and DDE are metabolites of DDT, separating contamination from metabolic accumulation is sometimes difficult. The metabolites of DDT are very persistent and are bioconcentrated to a high degree (EPA, 1980). DDT in water is acutely toxic to freshwater fish at concentrations as low as 0.8 ppb and to freshwater invertebrates at concentrations as low as 0.18 ppb. Chronic toxicity has been observed in the fathead minnow between the range of 0.37 to 1.48 ppb (EPA, 1980). DDT is a carcinogen (Verschueren, 1983). DDE is acutely toxic to freshwater aquatic life at concentrations as low as 1,050 ppb. Acute toxicity would occur at lower concentrations among species that are more sensitive than fish, such as invertebrate freshwater species. The 48-hour LC50 for *Daphnia* in water has been reported as 1.48 ppb. Crayfish had a 96-hour LC50 value of 0.18 ppb (EPA, 1980).

DDT and DDE were detected at concentrations of 25 ppb and 27 ppb, respectively, in the sediment at Site 25. These values exceed the NOAA ER-M guideline of 7 ppb for DDT, and 15 ppb for DDE. DDT and DDE were detected in soils at maximum concentrations of 200 and 26 ppb, respectively. DDT and DDE were not detected in surface water.

Dieldrin

The toxicity of dieldrin in water has been investigated in numerous studies. Reported 96-hour LC50 water values for freshwater fish range from 1.1 to 9.9 ppb for rainbow trout, 16 to 36 ppb for fathead minnows, and 8 to 32 ppb for bluegill (EPA, 1980). Freshwater invertebrates appear to be more variable in their sensitivity to dieldrin. The LC50 values range from 0.5 ppb for the stone fly to 740 ppb for crayfish (EPA, 1980).

Dieldrin was detected at a concentration of 13,000 ug/kg (ppb), which exceeds the NOAA ER-M guideline of 3,600 ppb, in sediment at Site 2B. Dieldrin was detected in soils at a maximum concentration of 21 ppb (Site 16). Dieldrin was not detected in surface water. The maximum dieldrin concentrations in sediment were 0.56 ppb at Site 22 and 56 ppb at Site 25. Dieldrin was not detected in sediments at Site 1 or Site 2B.

Iron

Iron is a very common element. Iron occurs naturally in high concentrations in clayey soils. Surface waters can sometimes have iron concentrations in the several mg/kg range, but these concentrations seem to have little effect on aquatic life (EPA, 1987). When taken orally, iron is not extremely toxic. However, when introduced directly into the bloodstream, which is not likely to occur under natural circumstances, iron can be instantaneously toxic (Clayton and Clayton, 1981). Lowest toxic doses (60 mg/kg oral) primarily affected the central nervous system of an adult rat (Clayton, *et al.*, 1981).

Surface water concentrations at Sites 1, 22, and 25 were somewhat above water quality and human-health criteria, as shown in Table A-10.

Lead

Lead is a ubiquitous element, being a natural constituent in the earth's crust. Most natural groundwaters have concentrations ranging from 1 to 10 ppb (EPA, 1980). Lead may affect fetal development in terrestrial organisms that ingest certain quantities of soil or water contaminated with lead. Administration of lead in the drinking water of rats at concentrations of up to 250 ppb delayed fetal development and fetal resorption (EPA, 1980). Chronic renal and neurological effects also have been produced by ingestion in laboratory experiments with mammals (Clayton and Clayton, 1981).

Lead was detected in a maximum concentration of 242,000 ppb in onsite soils. This concentration exceeds the background for soils in the eastern United States, which is 14,000 ppb. There is no proposed RCRA action level for lead. Lead was not detected in surface water.

Manganese

Data regarding the toxicity of manganese to freshwater aquatic life have reported tolerance values in the range of 1.5 mg/l (1,500 ppb) to over 1,000 mg/l (1,000,000 ppb). Therefore, manganese is not considered to be a problem in fresh water (EPA, 1987).

Manganese was detected in surface water at a maximum concentration of 114 ppb, which exceeds health criteria for the ingestion of water and fish (50 ppb). Human health criteria, in this case, were used to screen COCs on the basis of the assumption that the criteria may be conservative as applied to terrestrial organisms because of differences in biomass and metabolism.

Mercury

Mercury and its compounds have no known biological function, and the presence of the metal in the cells of living organisms is undesirable and potentially hazardous. In addition, forms of mercury with low toxicity can be transformed into forms with very high toxicity, such as methylmercury, through biological and other processes. Mercury poisoning has been known to produce reproductive failure, abnormal fetal development, and brain and pulmonary malfunctions (EPA, 1980). Concentrations of total mercury that are lethal to sensitive species range from 0.1 to 2.0 ppb for aquatic organisms; 2,200 to 40,000 ppb/kg body weight for birds; and from 100 to 5,000 μg/kg diet for mammals (Eisler, 1987). Significant adverse sublethal effects were observed among selected aquatic species at concentrations of 0.03 to 1.0 ppb. For the protection of sensitive species of mammals and birds that regularly consume fish and other aquatic organisms, total mercury concentrations should not exceed 100 μg/kg fresh weight for birds, and 1,100 μg/kg for small mammals (Eisler, 1987). Mercury is rapidly bioconcentrated in the food chain, although certain organisms are not necessarily adversely affected by high concentrations of mercury in various tissues (Eisler, 1987; EPA, 1980).

Mercury was not detected in onsite surface water above its IDL of 0.07 ppb. However, to be conservative, the surface water concentration was assumed to be equal to the IDL for the purposes of this analysis. The IDL exceeds the water quality criterion for aquatic organisms, which is 0.012 ppb. However, mercury in small concentrations may have effects in the potential receptors, as noted above.

Polynuclear Aromatic Hydrocarbons

Polynuclear aromatic hydrocarbons (PAHs) are a class of multi-ring aromatic compounds that include anthracene, benzo(a)anthracene, benzo(a)pyrene, chrysene, fluoranthene, phenanthrene, and pyrene.

PAH-related health effects for laboratory animals and humans include dermal disorders; immunosuppressive disorders; and reproductive, mutagenic, and carcinogenic effects (EPA, 1986 and Doull and Klassen, 1991). Pertinent data concerning toxicity to freshwater organisms are limited. The following toxicity information pertains to the individual PAHs listed above, except for fluoranthene, for which no freshwater chronic or acute toxicity data were available.

Acute toxicity to marine organisms from PAHs in water has been observed at a concentration of 300 ppb (EPA, 1986). PAH levels in drinking water that may result in carcinogenic effects in humans range from 0.28 ng/l (parts per trillion) to 28.0 ng/l (EPA, 1986). For pyrene, the 96-hour median threshold limit (TLM) for mosquito fish (*Gambusia* sp.) is 2.6 ppb. For chrysene and benzo(a)pyrene, the 96-hour TLM for (*Neanthes* sp.) is greater than 1,000 ppb, and for fluoranthene, the 96-hour TLM is 500 ppb (Verschueren, 1983). Fluoranthene is ubiquitous in the environment, having been found in food, water, and air (EPA, 1980). The EC50 value for *Daphnia* is 325,000 ppb (EPA, 1986). The 96-hour LC50 value for bluegill is reported to be 3,980 ppb (EPA, 1980). The 24-hour no-effect level for trout from anthracene exposure is 5,000 ppb. The low-effect level for an arthropod from phenanthrene exposure is 8,000,000 ppb (Verschueren, 1983).

Anthracene, benzo(a)anthracene, benzo(a)pyrene, chrysene, fluoranthene, phenanonthrene, and pyrene were detected at concentrations about NOAA guidelines in sediment at Site 2B. These PAHs were detected in Site 2B sediment at the following maximum concentrations versus the ER-M guidelines: Anthracene at 2,200 ppb versus the NOAA ER-M guideline of 960 ppb; benzo(a)anthracene at 6,000 ppb versus 1,600 ppb; benzo(a)pyrene at 6,400 ppb versus 2,500 ppb; chrysene at 7,900 ppb, versus 2,800 ppb; fluoranthene at 13,000 ppb versus 3,600 ppb; phenanthrene at 7,400 ppb versus 1,380 ppb; and pyrene at 11,000 ppb versus the NOAA ER-M guideline of 2,200 ppb.

Zinc

Several studies indicate that acute toxicity of zinc in water decreases as hardness increases. Adjusted to a hardness of 50 ppm (mg/l), sensitivity ranges from 50.7 ppb (μg/l) for *Daphnia* to 88,960 ppb for a species of damselfly. Other data indicate that toxicity increases as temperature increases. Chronic toxicity values for *Daphnia* ranged from 46.73 ppb to greater than 5,243 ppb for a species of caddisfly. Chronic values for fish ranged from 36.41 ppb for flagfish to 854.7 ppb for brook trout. Zinc has been found to bioaccumulate in freshwater aquatic animal tissues at ratios of 50 to more than 1,000 times the concentration present in water. The range of sensitivity of freshwater plants to zinc is greater than that for animals. Growth of algae was inhibited at concentrations ranging from 30 ppb to 200,000 ppb (EPA, 1986).

Zinc was detected in sediments at a concentration of 723,000 ppb, which exceeds the NOAA ER-M guideline of 270,000 ppb, at Site 25. Zinc was detected at a maximum concentration of 257,000 ppb in soils, which is above the mean background concentration for soils in the eastern United States of 40,000 ppb. Soil concentration maximums at Sites 2E (105,000 ppb) and 18 (121,000 ppb) also were above this mean concentration. The maximum concentrations of zinc in surface water during the RFI was 32.5 ppb, at Site 1.

Summary

The environmental assessment component of the HEA described in this appendix included a description of the ecosystem at NAS Oceana, containing observations and existing inventories of plants and animals known from the site or area. Potential receptors, including vegetation, wetlands, wildlife, fish, and threatened and endangered species, were included in these inventories.

Ecological COCs found in the surface water, sediment, and soil exceeded levels that produce chronic effects in aquatic life or are of concern because they exceeded agency established action levels or literature-derived background concentrations. Chemicals of concern were arsenic, antimony, beryllium, cadmium, lead, manganese, mercury, methylene chloride, and silver. Most COCs were not detected in concentrations that greatly exceeded criteria.

The assessment also included a survey of potential environmental effects from exposure to potential COCs. The information contained in the assessment is derived chiefly from secondary resources and available reference material. Because of the possible limitations of such sources, this assessment may not reflect all available information about possible environmental effects posed by the potential COCs.

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Appendix B
Hydraulic Probe Groundwater Sampling Procedures

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Hydraulic Probe Groundwater Sampling Procedures

The RFI field investigation began with in-situ groundwater sampling with a hydraulic probe at Sites 2B, 2C, and 15. The groundwater samples collected with the probe were analyzed onsite within hours using a laboratory-grade gas chromatograph equipped with two high-sensitivity detectors. This approach allowed the characterization of these three sites to proceed rapidly, without the delays of traditional laboratory analysis. This work also allowed CH2M HILL and the Navy to choose appropriate locations for monitoring wells installed at Sites 2B and 2C later in the investigation. Strict field sampling and field laboratory Quality Assurance/Quality Control (QA/QC) procedures were followed to ensure the integrity of the analytical data and to comply with Navy and EPA data requirements. The hydraulic probe sampling and onsite analysis was performed by Envirosurv, Inc. of Fairfax, Virginia.

The samples were collected using a hydraulic sampling probe mounted on a 4-wheel drive truck. In general, groundwater samples were collected from 9 to 12 feet at Sites 2B and 2C and from 6 to 9 feet at Site 15; however, two samples were collected from 15 to 18 feet in the eastern source area at Site 2B. *In situ* sampling involves driving a 3/4-inch diameter 3-foot slotted lead rod to the appropriate depth using a percussion hammer, then collecting the groundwater sample through polypropylene tubing. The tubing is pumped up and down to bring the water to the surface, where it is collected into vials for onsite analysis.

Sample splits were collected by CH2M HILL for analysis at CH2M HILL's offsite labs as a confirmation of field results. Sample splits were also collected by Dynamac, Inc. on behalf of the EPA.

The contaminants of concern were halogenated volatile organic compounds at Site 2B and 2C and fuel compounds at Site 15; however, all samples were analyzed for both types of contaminants. Both an electron capture detector and a flame ionization detector were used to identify and quantify contaminants. The target compounds listed on the following page were analyzed.

The last parameter, total petroleum volatiles, is a composite analysis that indicates the approximate total concentration of all volatile petroleum constituents in the sample. Because fuel consists of hundreds of compounds, it is a good general indicator of fuel contamination particularly for cases in which the single-ring compounds; benzene, toluene, ethylbenzene, and xylene (BTEX) have volatilized or broken down but other constituents remain.

Compound	Quantitation Limit (ug/l)
Chlorinated volatile organics:	
Vinyl chloride	2.0
1,1-Dichloroethylene	2.0
trans-1,2-Dichloroethylene	2.0
cis-1,2-Dichloroethylene	2.0
1,1-Dichloroethane	2.0
1,1,1-Trichloroethane	0.5
Trichloroethylene	0.5
Fuel-related aromatic organics:	
Benzene	10.0
Toluene	10.0
Ethylbenzene	10.0
Total xylenes	10.0
Total petroleum volatiles (TPV)	10.0

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Appendix C
Drilling Activities

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Procedures

Introduction

The drilling and installation of 25 monitoring wells at NAS, Oceana took place from December 2, 1992, to January 13, 1993. The drilling was performed by Hardin-Huber, Incorporated of Baltimore, Maryland, under the supervision of CH2M HILL. Eighteen wells were shallow, extending to depths of 20 feet to 24 feet. Installing wells at these depths enabled CH2M HILL to sample groundwater from the upper part of the local, unconfined aquifer, otherwise known as the Columbia Group sediments. In addition to the shallow wells, seven deep monitoring wells were installed from 51 to 65 feet. These wells were designed to sample groundwater from the Yorktown Formation, which locally underlies surficial deposits. During drilling operations, shell fragments, which are characteristic of the Yorktown Formation, were typically first encountered in trace amounts at 23 to 25 feet and increased in abundance with depth. At 2C-MW1D, the shell fragments were not encountered until a depth of 33 feet. Given the total borehole depths of the deep monitoring wells, it is clear that the wells penetrate the Upper Yorktown Formation.

Shallow Monitoring Wells

The boreholes for all shallow monitoring wells were drilled using 6-inch or 8-inch-inside-diameter (ID) hollow-stem augers. The drilling was typically performed using a Mobile B-80 or Mobile B-57 rig; however, limited access to proposed monitoring well locations at Site 1 and Site 22 required the use of a Mobile B-53 all-terrain rig. During drilling, 24-inch split spoon samples were collected on 5-foot intervals. CH2M HILL personnel recorded the lithologic and geotechnical characteristics of the sediments encountered, as well as the apparent depth to water, moisture content and drilling resistance. Complete soil-boring logs of each borehole are included in this appendix.

The drilling operations were hindered by the presence and effects of fluid sands, which tend to run-up into the augers. This impediment was countered in two ways. To decrease the amount of run-up, smaller inside-diameter augers were utilized for sampling, and the larger 6-inch or 8-inch ID augers were then capped with wooden plugs and used to ream the entire length of the borehole. Another countermeasure to running sands was to place a tri-cone bit in the borehole, attach the hammer and hammer the material out of the augers. The effectiveness of both techniques was tested and often required second and third attempts in order to accurately sample at a certain depth. No water was added to the subsurface during drilling except in two limited cases where water became necessary to clear the hole. An equal or greater volume of water was removed from the well during development.

As mentioned earlier, the boreholes were advanced to 20 to 24 feet below the ground surface. The well installation depth was determined by CH2M HILL hydrogeologists in the field based on drilling 15 feet deeper than the water table, and setting the well. All drill cuttings were placed in 55-gallon steel drums. The drums were sealed and labelled during drilling.

The monitoring wells were constructed of 2-inch ID Schedule 40 PVC well pipe and screen. The screen lengths were 10 feet with 0.01-inch slots. At most of the sites, the top of the screen was placed approximately 5 feet below the apparent water table in the shallow wells and a minimum of 10 feet into the Yorktown in the deep wells. Screen placement will aid in determining whether dissolved contamination is migrating away from the site. Concentrations from wells screened near the water table can also be used to judge whether floating free product is present above the water table. At Sites 1 and 11, where fuels were disposed, the screens were placed across the water table to intercept possible floating free product hydrocarbons and, therefore, were 15 feet in length. All well piping and screen was joined by threaded, flush-joint connections; no glues or solvents were used in well construction. The annular space between the well and the borehole was backfilled with No. 2 clean sand throughout the screened interval; this sand pack will extend to approximately 2 feet above the screen. A bentonite seal with a thickness of 2 feet was placed above the sand pack. The remaining annular space was grouted to the surface with a cement/bentonite mix with approximately 4 pounds of powdered bentonite per bag of cement. The grout was added to the annulus using a tremie pipe with a side-flow outlet when the depth to bentonite was greater than 4 feet. A steel protective casing was set into the grout. The casings have locking caps to restrict access to the monitoring well. Table C-1 lists the exact specifications of each monitoring well installed as part of this RFI.

The wells were completed above grade with a 3- to 3½-foot diameter concrete pad and four guard posts except those wells installed in high vehicle traffic areas. In these areas, the wells were completed below grade with flush-mounted steel covers for protection.

Following well installation, all new shallow monitoring wells were developed to remove residual fine-grained material from around the sand pack. The development equipment, which included a centrifugal pump, tubing and a foot valve, was decontaminated prior to use in each well. Well development was initiated by surging water into and out of the well's screened portion with a foot valve serving as a surge block. The wells were then pumped to remove sediment that had entered the well during surging. Pumping rates on the shallow wells ranged from 4 to 10 gallons per minute as estimated by field measurements. The discharge was monitored to detect a reduction in the turbidity of the pump water during successive surge and pump cycles. Pumping ceased once the discharge water was determined to be relatively free of suspended solids. The development water from all new wells at Site 2C and from 2B-MW16, 2B-MW5D and 2B-MW1D, was contained in tanker trucks and disposed because of potential unacceptable risks to human health and the environment.

Table C-1
INSTALLATION RECORD OF MONITORING WELLS INSTALLED DURING RFI

Well	Ground Elevation (Ft. above MSL)	Grout Interval (feet)	Bentonite Interval (feet)	Sand Interval (feet)	Screened Interval (feet)	Total Borehole Depth[c] (feet)
1-MW6	15.4	0 - 2	2 - 4	4 - 20.5	5.5 - 20.5	20.5
1-MW7	17.2	0 -3.5	3.5 - 5.5	5.5 - 22.5	7.5 - 22.5	22.5
1-MW7D	17.3	0 - 39.5	39.5 - 42.3	42.3 - 55	45 - 55	57
1-MW8	15.2	0 - 2.5	2.5 - 4.5	4.5 - 22	7 - 22	22
1-MW8D	15.4	0 - 38	38 - 41	41 - 55	45 - 55	55
1-MW9D	15.3	0 - 42	42 - 46	46 - 60	50 - 60	65
2B-MW1D	21.73	0 - 30.5	30.5 - 33[a]	33 - 46	36 - 46	55
2B-MW5D	21.8	0 - 32	32 - 34	34 - 47	37 - 47	51
2B-MW12	18.4	0 - 8	8 - 10	10.0 - 22.6	12.6 - 22.6	22.5
2B-MW13	17.9	0 - 3.5	3.5 - 7.5	7.5 - 21	11 - 21	21
26-MW14	17.4	0 - 5	5 - 7	7 - 20	9 - 19	20
2B-MW15	19.0	0 - 6	6 - 8	8- 22.5	12.5 - 22.5	22.5
2B-MW16	21.16	0 - 4	4 - 8	8 - 20	10 - 20	20
2C-MW1D	20.43	0 - 39	39 - 42	42 - 55	45 - 55	62
2C-MW9D	17.1	0 - 34	34 - 36[b] 38 - 39	39 - 52	42 - 52	57
2C-MW10	18.24	1 - 5	5 - 8	8 - 20	10 - 20	20
2C-MW11	18.47	1 - 6	6 - 8	8 - 24	13 - 23	24
2C-MW12	17.84	1 - 6	7 - 9	9 - 24	13 - 23	24
2C-MW13	18.49	1 - 7	7 - 9	9 - 22	11 - 21	22

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Table C-1
INSTALLATION RECORD OF MONITORING WELLS INSTALLED DURING RFI

Well	Ground Elevation (Ft. above MSL)	Grout Interval (feet)	Bentonite Interval (feet)	Sand Interval (feet)	Screened Interval (feet)	Total Borehole Depth[c] (feet)
11-MW2	16.6	0 - 2.5	2.5- 4.0	4.0 - 20.5	5.5 - 20.5	20.5
11-MW3	17.33	0.5 - 2.0	2 - 3	3 - 20	5 - 20	20
22-MW1	16.0	0 - 5	5 - 7	7 - 20	9.5 - 19.5	20
22-MW2	15.6	0 - 12	12 - 15	15 - 28	18 - 28	28
22-MW3	19.2	0 - 9	9 - 11	11 - 23	13 - 23	23
22-MW4	16.6	0 - 9	9 - 11	11 - 23	13 - 23	23

[a]There is a Lower Bentonite Seal from 47.0 - 50.5
[b]There is a Lower Bentonite Seal from 53 - 57
[c]These depths are estimated from the well logs and drilling field notes

Note: At some wells, the borehole depth does not equal the bottom of either the screened interval or sand intervals because the driller overdrilled to account for running sands.

The drill rig and all equipment used during drilling such as augers, sampling rods, and split-spoon samplers were decontaminated before drilling began and after it was completed. Decontamination also occurred between boreholes in order to avoid cross-contamination. When collecting the soil borings at Sites 1, 2B, and 2C, the sampling equipment was decontaminated between sample depths within all boreholes. Thick accumulations of drill cuttings were removed from the equipment before the decontamination procedures began. These soil cuttings were contained in 55-gallon steel drums. The driller provided decontamination pads on which the augers were cleaned with a high-pressure steam cleaner. The pads were designed to contain any wastes derived from the decontamination process. Containment was achieved by 1-foot high walls, which surround the pad. The rinse water was allowed to drain freely, but excess soil cuttings were placed in drums.

Deep Monitoring Wells

The scope of the NAS, Oceana RFI required the installation of seven deep monitoring wells: 1-MW7D, 1-MW8D, 1-MW9D, 28-MW1D, 2B-MW5D, 2C-MW1D, and 2C-MW9D. These wells penetrate the Upper Yorktown Formation an average of 25 feet. The deep well depths range from 51 feet to 65 feet below grade. The drilling of these wells was completed with 6.25 inch ID hollow stem augers driven by the Mobile B-53 all terrain rig, and the Mobile B-80 rig where site conditions allowed. The distinct confining layer of blue-green marine clay known to overlay the Yorktown Formation in some areas was not encountered; therefore, the installation of permanent casings to inhibit the influence of the shallow zone on the deeper wells was not necessary. Sampling for lithologic and geotechnical characteristics proceeded on 5-foot intervals with 24-inch split spoons. As with the shallow wells, fluid sands drastically slowed the sampling effort and similar techniques for countering the fluid sands were employed. Complete borehole logs are included in this appendix.

Well installation, development, and decontamination procedures were the same for the deep wells as the procedures described earlier in the shallow monitoring well section. It is noteworthy to mention that bridging of the bentonite pellets occurred during application to the annulus as a direct result of the large water depths through which the pellets had to filter on the way to their final destination atop the sand pack. The bridging lead to the development of two bentonite seals in 2B-MW1D and 2C-MW9D.

WDCR706/010.51

Soil Boring Logs

Included in this section:

1. Soil Boring Logs

   - Site 1: 1-SB1 through 1-SB15 (Table C-2)
   - Sites 2B/2C: 2C-SB1 through 2C-SB3, 2B-SB2, 2B-SB5 through 2B-SB7 (Table C-3)

2. Soil Boring Logs for Monitoring Wells Installed During the RFI

   - 1-MW6
   - 1-MW7
   - 1-MW7D
   - 1-MW8
   - 1-MW8D
   - 1-MW9D
   - 2B-MW1D
   - 2B-MW5D
   - 2B-MW12
   - 2B-MW13
   - 2B-MW14
   - 2B-MW15
   - 2B-MW16
   - 2C-MW1D
   - 2C-MW9D
   - 2C-MW10
   - 2C-MW11
   - 2C-MW12
   - 2C-MW13
   - 11-MW2
   - 11-MW3
   - 22-MW1
   - 22-MW2
   - 22-MW3
   - 22-MW4

3. Soil Boring Logs for Monitoring Wells Installed Prior to the RFI

   - 2B-MW1[a]
   - 2B-MW5[b]
   - 2B-MW1[b]
   - 2B-MW9[c]

[a]Final Progress Report, Round 1 Verification Study, CH2M HILL 1986.
[b]Line Shack Site Inspection Final Report, CH2M HILL 1989.
[c]Interim RCRA Facility Investigation Final Report, CH2M HILL 1991.

These borehole logs have been included because they compliment the deep monitoring wells installed as part of the RFI.

WDCR706/011.51

Table C-2
SITE 1 SOIL BORING DATA
DECEMBER 2, 29-30, 1992

Boring	Depth (ft)	Blow Counts	Recovery (ft)	Monitoring (ppm)	Lithology	Comment
1-SB1	0-2	2-4-9-10	1.8	BZ = BG HS = 0	SILT (ML) WITH TRACE SAND, dark yellowish brown (10 YR 4/2) stiff, moist, sand is very fine	
	2-4	6-6-6-5	1.3	BZ = BG HS = 15	SILT WITH SOME SAND (ML), same as 0-2 ft but 10-15% very fine sand	
	4-6	2-3-4-6	2	BH = 15 HS = 45	0-1.3′: SILT (ML), like 0-2 ft; 1.3-2.0′: POORLY-GRADED SAND WITH SILT (SP-SM), light olive gray (5 Y 6/1), loose, moist, sand is very fine to fine	Slight fuel odor
	6-8	8-12-17-19	1.6	HS = 65	WELL-GRADED SAND (SW), medium light gray (N6), medium density, wet	Very strong fuel odor NO ANALYTICAL SAMPLING
1-SB2	0-2	1-9-8-11	1.2	BZ = BG HS = 1,000	SANDY SILT (ML), light gray (N7), medium density, moist, sand is very fine to fine	Slight fuel odor
	2-4	3-3-3-4	2.0	BH = 120 HS >> 1,000	SILT WITH SAND (ML), light olive gray (5 Y 6/1), firm, moist	Fuel odor
	4-6	2-2-9-12	2.0	BZ = BG BH > 1,000 HS = 1,000 Explo > lower explosive limit	0-1.0′: SILT WITH SAND (ML), like 2-4 ft; 1-1.2′: POORLY-GRADED SAND WITH SILT (SP-SM), same color, loose, wet; 1.3-2.0′: POORLY-GRADED SAND (SP), same color, stiff, wet	Very strong fuel odor sheen on spoon NO ANALYTICAL SAMPLING

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Table C-2
SITE 1 SOIL BORING DATA
DECEMBER 2, 29-30, 1992

Boring	Depth (ft)	Blow Counts	Recovery (ft)	Monitoring (ppm)	Lithology	Comment
1-SB3	0-2	3-5-6-8	0.7	BZ = BG HS = 1	SILT (ML) dark yellowish brown (10 YR 4/2), stiff, moist	No odor
	2-4	2-2-2-4	0.5	BZ = BG BH = 300 HS = 1	SILTY SAND (SM), same color, loose, moist, ~30% silt	Metal debris from 2-4 feet
	4-6	2-2-1-1	0	-	No sample	-
	6-8	5-9-10-12	0.7	BZ = BG BH = 1,000 HS > 1,000	POORLY-GRADED SAND (SP), medium light gray (N6), medium density, wet, sand is well-rounded, fine to medium sand	Strong fuel odor
	8-10	10-14-15-18	2.0	BZ = BG BH = 200	POORLY-GRADED SAND (SP), same as 6-8 ft	Very strong fuel odor; sheen on spoon NO ANALYTICAL SAMPLING
1-SB4	0-2	2-2-3-5	0.9	BZ = BG BH = 1	SILT (ML), pale yellowish brown (10 YR 6/2), soft, moist	No odor
	2-4	2-1-1-3	1.4	BZ = BG HS = BG	SANDY SILT (ML), same color, soft, moist	
	4-6	3-9-11-19	2.0	BZ = BG BH = 1,000 HS = 300	0-0.3': SANDY SILT (ML), like 2-4 ft; 0.3-1.1': POORLY-GRADED SAND (SP), dark yellowish orange (10 YR 6/6) to dusky yellow (5 Y 6/4), medium density, dry, sand is very fine; 1.1-2.0': POORLY-GRADED SAND (SP), light gray (N7) to light olive gray (5 Y 6/1), medium to dense, dry, sand is fine to medium	Very strong fuel odor

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Table C-2
SITE 1 SOIL BORING DATA
DECEMBER 2, 29-30, 1992

Boring	Depth (ft)	Blow Counts	Recovery (ft)	Monitoring (ppm)	Lithology	Comment
1-SB4 (Cont)	6-8	16-22-23-30	1.4	BZ = BG BH = 400 HS = 700	POORLY-GRADED SAND (SP), same as 5-6 ft	Very strong fuel odor
	8-10	10-14-15-17	1.7	HS > 1,000	POORLY-GRADED SAND (SP), light gray (N7) medium density, wet, sand is well-rounded, medium	Sheen on spoon; very strong fuel odor NO ANALYTICAL SAMPLING
1-SB5	0-2	1-4-6-6	1.6	BZ = BG HS = 0.5	SILT (ML), dark yellowish brown (10 YR 4/2), firm, moist	No odor
	2-4	3-2-4-3	2.0	BZ = BG HS = 1	SILT WITH SAND (ML), some odor, firm, moist, sand is very fine	
	4-6	2-3-6-8	2.0	BZ = BG HS = 4	SILTY SAND (SM), pale yellowish orange (10 YR 6/2), loose to medium, moist, sand is very fine	
	6-8	15-17-20-22	1.8	BZ = BG HS = 20	WELL-GRADED SAND (SW), pale yellowish orange (10 YR 8/8), dense, wet, sand is fine to coarse	
	8-10	7-9-11-14	1.6	BZ = BG HS = 10	0-0.8′: WELL-GRADED SAND (SW), grayish yellow (5 Y 8/4), medium density, wet, sand is medium to very coarse; 0.8-1.6′: POORLY-GRADED SAND, same color, medium, wet, sand is fine, well-rounded	NO ANALYTICAL SAMPLING

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Table C-2
SITE 1 SOIL BORING DATA
DECEMBER 2, 29-30, 1992

Boring	Depth (ft)	Blow Counts	Recovery (ft)	Monitoring (ppm)	Lithology	Comment
1-SB6	0-2	2-2-3-3	0.5	BZ = BG HS = 2	SILT (ML), yellowish brown (10 YR 4/2), firm, moist	
	2-4	2-3-5-2	1.0	BZ = BG HS = BG	0-0.7′: SILT (ML), like 0-2; 0.7-1.0′: SILTY SAND (SM), black (N2) and dark yellowish orange (10 YR 6/6), firm, moist	Contains glass, oil, or fuel odor
	4-6	2-3-4-9	0.9	BZ = BG HS = 1	0-0.4′: SILTY SAND (SM) as above 3-4 ft; 0.4-0.9′: POORLY-GRADED SAND (SP), grayish yellow (5 Y 8/4), medium density, moist, sand is fine	Slight fuel odor
	6-8	16-19-21-22	1.8	BZ = BG HS = 0.5	POORLY-GRADED SAND (SP), yellowish gray (5 Y 7/2), medium density, moist, sand is fine to medium, bottom 2 inches color changes to dark yellowish orange (10 YR 6/6), moisture content is moist to wet	
	8-10	11-9-17-19	1.4	BZ = BG HS = 100	0-0.5′: WELL-GRADED SAND (SW), dark gray (N3), medium density, wet; 0.5-0.8′: same sand but yellowish gray (5 Y 8/1); 0.8-1.4′: same sand but light gray (N7)	Fuel odor NO ANALYTICAL SAMPLING
1-SB7	0-2	3-4-6-6	-	HS = 10	SANDY SILT (ML), brown	
	2-4	2-5-5-5	-	HS = 35	SANDY SILT (ML), brown	
	4-6	2-1-1-2	-	HS = 5	SILT (ML), brown	Concrete bits

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Table C-2
SITE 1 SOIL BORING DATA
DECEMBER 2, 29-30, 1992

Boring	Depth (ft)	Blow Counts	Recovery (ft)	Monitoring (ppm)	Lithology	Comment
1-SB7 (Cont)	6-8 Drive #1	35-50/4	-	HS = 20	SANDY SILT (ML), brown	Glass and metal debris
	Drive #2	24-58-63-60	-	HS = 250	0-0.7′: SANDY SILT (ML), brown; 0.7-1.5′: POORLY-GRADED SAND (SP), gray with black streaks	COLLECTED APPENDIX IX SAMPLE FROM 7 TO 8 FEET IN SAND
1-SB8	0-2	3-4-6-5	-	HS = 0	SILT TO SANDY SILT (ML), brown, dry	
	2-4	7-10-9-4	-	HS = 0	SILT TO SANDY SILT (ML), same as 0-2 ft	
	4-6	4-6-11-16	2.0	HS = 0	0-1′: SILT TO SANDY SILT (ML), same as 0-2 ft; 1-2′: POORLY-GRADED SAND (SP), tan to orange, well-rounded, no silt	No odor
	6-8	11-14-20-28	-	HS = 2	WELL-GRADED SAND (SW), tan to orange, no silt	COLLECTED FOUR-PARAMETER SERIES FROM 6 TO 8 FT
1-SB9	0-2	1-5-8-6	-	HS = 7	SILT (ML)/CLAY (CL), brown	
	2-4	3-2-3-4	-	HS = 100	SILTY CLAY (CL), brown	Fuel odor
	4-6	4-3-2-8	2.0	HS > 1,000	0-1′: SILTY CLAY (CL), brown; 1-2′: POORLY-GRADED SAND (SP), gray, no silt	Some rubble in 2nd boring

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Table C-2
SITE 1 SOIL BORING DATA
DECEMBER 2, 29-30, 1992

Boring	Depth (ft)	Blow Counts	Recovery (ft)	Monitoring (ppm)	Lithology	Comment
1-SB9 (Cont)	6-8	16-20-23-22	-	HS >> 1,000	POORLY-GRADED SAND (SP), light gray, sand is fine to medium	Strong fuel odor COLLECTED APPENDIX IX SAMPLE WITH QC FROM 3 TO 5 FT IN CLAY COLLECTED PRE-CMS SAMPLE FROM 0 TO 2 FT IN CLAY
1-SB10	0-2	2-6-6-7	-	HS = 0	SILTY SAND (SM), beige	Slight fuel odor, glass shards
	2-4	6-3-1-2	-	HS = 0	SILT (ML), brown	
	4-6	2-4-4-10	1.2	HS > 1,000	0-0.3′: SILT (ML)/CLAY (CL), reddish; 0.3-1.2′: POORLY-GRADED SAND WITH SILT (SP-SM), gray	Glass in silt/clay
	6-8	15-22-19-16	-	HS = 300	POORLY-GRADED SAND (SP), gray, no silt	Strong fuel odor COLLECTED PRE-CMS SAMPLE FROM 4 TO 6 FT COLLECTED FOUR-PARAMETER SERIES FROM 6 TO 8 FT
1-SB11	0-2	2-2-2-2-	-	HS = 0	WELL-GRADED SAND (SW), tan, very loose to loose, dry	No odor
	2-4	2-2-2-2-	-	HS = 35	SAND (SW), same as 0-2 ft but wet	
	4-6	-	2.0	HS = 2	0-1′: SAND (SW), same as 0-2 ft; 1-2′: SILT (ML), gray	Strong fuel odor in silt

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Table C-2
SITE 1 SOIL BORING DATA
DECEMBER 2, 29-30, 1992

Boring	Depth (ft)	Blow Counts	Recovery (ft)	Monitoring (ppm)	Lithology	Comment
1-SB11 (Cont)	5-7	-	2.0	HS = 700	SANDY SILT (ML)/SILTY SAND (SM), gray	Very strong fuel odor COLLECTED VOCs FROM 5 TO 6 FT AND PAHs, METALS, PCBs FROM 5 TO 7 FT
1-SB12	0-2	3-3-4-3	-	HS = 0	SILT (ML), brown	
	2-4	3-4-4-8	-	HS = 0	SAND WITH SILT (SP-SM), gray to orange tan	
	4-6	9-18-25-27	-	HS = 150	POORLY-GRADED SAND (SP), gray, dense, moist	Fuel odor
	6-8	16-15-22-19	-	-	WELL-GRADED SAND (SW), gray dense, sand is fine sand to fine gravel (2 mm)	Strong fuel odor, sheen COLLECTED PRE-CMS SAMPLES FROM 4 TO 6 FT COLLECTED FOUR-PARAMETER SERIES IN SAND FROM 6 TO 8 FT
1-SB13	0-2	2-2-3-6	2.0	HS = 0	SILT (ML), brown	
	2-4	2-3-3-4	2.0	HS = 0	0-1': SILT (ML), brown; 1-2': SILTY SAND (SM), gray to orange	
	4-6	9-19-21-40 (with 3" ID split spoon)	-	HS = 200	POORLY-GRADED SAND (SP), gray, no silt	Strong fuel odor COLLECTED FOUR-PARAMETER SERIES WITH QC FROM 4 TO 6 FT IN SAND

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Table C-2
SITE 1 SOIL BORING DATA
DECEMBER 2, 29-30, 1992

Boring	Depth (ft)	Blow Counts	Recovery (ft)	Monitoring (ppm)	Lithology	Comment
1-SB14	0-2	1-2-4-3	-	HS = 20	SILT (ML), brownish gray, dry	
	2-4	2-3-3-3	-	HS = 10	SANDY SILT (ML), brownish gray	
	4-6	2-4-10-16	2.0	HS = 200	0-1': SANDY SILT (ML), like 2-4 1-2': POORLY-GRADED SAND (SP), gray, no silt	Strong fuel odor COLLECTED FOUR-PARAMETER SERIES FROM 5 TO 6 FEET IN SAND
1-SB15	0-2	3-4-4-4	-	HS = 15	SILT (ML), brownish gray, dry	
	2-4	2-3-4-7	-	HS = 0	SANDY SILT (SM), greenish gray, approximately 20-30% very fine sand	
	4.5-6.5	12-13-18-26 (with 3" ID split spoon)	-	-	POORLY-GRADED SAND WITH SILT (SP-SM), greenish gray	No odor COLLECTED FOUR-PARAMETER SERIES FROM 4.5 TO 6.5 FT

BH = Borehole (ppm)
BG = Background
BZ = Breathing Zone
HS = Sample jar headspace (ppm)

Appendix IX Soil Samples include: App. IX VOCs, App. IX Semivolatiles, App. IX Pesticides/PCBs, App. IX metals, cyanide, sulfide, App. IX Herbicides, App. IX Dioxin/Furan, and App. IX Organophosphorus Pesticides

The Four-Parameter Series includes: Metals, PCBs, PAHs, and Method 8240 VOCs

Pre-CMS Samples include: Particle size, cation exchange capacity (CEC), moisture content, total organic carbon (TOC), soil pH, and saturated pH. Not all these parameters were collected at all locations. Check the data tables in the appendices.

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Table C-3
SITE 2B AND 2C SOIL BORING DATA
DECEMBER 29-30, 1992

Boring	Depth (ft)	Blow Counts	Recovery (ft)	Monitoring (ppm)	Lithology	Comment
2B-SB2	0-2	3-5-10-10	1.8	BZ = BG	NR	No analytical sampling
	2-4	2-3-4-4	1.5	BH = BG	NR	*
	4-6	1-2-4-4	1.7	BH = 1	NR	*
	6-8	4-5-6-9	1.9	BZ = BG BZ = BG	NR	No analytical sampling
2B-SB5	1-3	13-13-15-18	1.0	BH = 2, BZ = BG	NR	No analytical sampling
	3-5	3-5-8-10	1.5	BH = 2, BZ = BG	NR	Pre-CMS, *
	5-7	2-3-3-3	2.0	BH = 5, BZ = BG	NR	Pre-CMS, *
2B-SB6	1-3	2-6-7-11	1.5	BZ = BG	NR	*
	3-5	4-3-3-5	1.0	BH = 5, BZ = BG	NR	*
	5-7	3-3-3-4	2.0	BZ = BG	NR	No analytical sampling
2B-SB7	1-3	10-10-15-12	1.5	BH = 3, BZ = BG	NR	No analytical sampling
	3-5	2-7-4-3	1.7	BH = 20, BZ = BG	NR	*
	5-7	1-2-3-3	1.8	BH = 3, BZ = BG	NR	*
2C-SB1	1-3	17-16-13-12	1.5	BZ = BG	NR	*
	3-5	5-2-4-2	1.5	BZ = BG	NR	*
	5-7	3-5-5-6	2.0	BZ = BG	NR	No analytical sampling
2C-SB2	1-3	10-15-19-21	2.0	BZ = BG	NR	No analytical sampling
	3-5	10-15-16-10	2.0	BZ = BG	NR	Pre-CMS, *
	5-7	2-5-8-6	2.0	BZ - BG	NR	Pre-CMS, *

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Table C-3
SITE 2B AND 2C SOIL BORING DATA
DECEMBER 29-30, 1992

Boring	Depth (ft)	Blow Counts	Recovery (ft)	Monitoring (ppm)	Lithology	Comment
2C-SB3	1-3	9-12-17-9	1.0	BH = 60 BZ = BG	NR	*
	3-5	5-5-6-6	1.5	BH = < 1000 BZ = BG	NR	Pre-CMS, *
	5-7	2-5-2-6	1.5	BZ = BG BZ = BG	NR	Pre-CMS

Key:

BZ = Breathing Zone
BH = Borehole (ppm)
BG = Background
NR = Not Recorded
* = Chlorinated Volatile Analysis
Pre-CMS Samples include: Particle size, moisture content, pH agricultural, and total organic carbon (TOC).

Note: All soil borings listed above were advanced with a B-61 drill rig and 4 ¼" hollow stem augers. Soil borings 2B-SB1, -SB3, -SB4, which are not listed in the table, were collected using a hand auger.

CH2M HILL

PROJECT NUMBER	BORING NUMBER	
HR020388.K0.02	1-MW8	SHEET 1 OF 1

SOIL BORING LOG

PROJECT NAS Oceana RFI LOCATION Near East-West ditch

ELEVATION 15.4 feet (Ground) DRILLING CONTRACTOR Hardin-Huber, Inc.

DRILLING METHOD AND EQUIPMENT B-53 ATU with 4 1/4 and 6 1/4 HSA

WATER LEVELS 8.8 feet 1/28/93 START 1/7/93 FINISH 1/8/93 LOGGER S. Brown

DEPTH BELOW SURFACE (FT)	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	COMMENTS
	INTERVAL	TYPE AND NUMBER	RECOVERY	6"-6"-6" (N)	SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	DEPTH OF CASING, DRILLING RATE DRILLING FLUID LOSS TESTS AND INSTRUMENTATION
	3					WELL SUMMARY Total depth = Screen = Sand = Bentonite = Grout = See Log Book #1 for information.
5.0	5	SS-1	2.0	6-4-6-7 (10)	LEAN CLAY (CL), light brownish gray (5 YR 6/1), soft to firm, moist.	
	8					Water table at approximately 7'.
10.0	10	SS-2	1.4	5-6-8-11 (14)	POORLY GRADED SAND (SP), medium light gray (N6), loose, wet, clean.	
	13					
15.0	15	SS-3	1.2	11-20-27-18 (47)	Same as SS-2.	
	19					
20.0	21	SS-4	1.8	5-3-1-1 (4)	POORLY GRADED SAND WITH SILT (SP-SM), olive gray, loose, wet, sand is very fine.	
					End of Boring @ 21'.	

CH2M HILL

PROJECT NUMBER	BORING NUMBER	
HRO20368.KO.02	1-MW7	SHEET 1 OF 1

SOIL BORING LOG

PROJECT NAS Oceana RFI **LOCATION** West side of North-South ditch

ELEVATION 17.2 feet (Ground) **DRILLING CONTRACTOR** Hardin-Huber, Inc.

DRILLING METHOD AND EQUIPMENT B-53 ATU with 6 1/4 HSA

WATER LEVELS 9.2 feet 1/26/93 **START** 12/22/92 **FINISH** 12/23/92 **LOGGER** S. Brown

DEPTH BELOW SURFACE (FT)	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	COMMENTS
	INTERVAL	TYPE AND NUMBER	RECOVERY (FT)	6"-6"-6" (N)	SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	DEPTH OF CASING, DRILLING RATE DRILLING FLUID LOSS TESTS AND INSTRUMENTATION
0					Refer to boring 1-MW7D for lithologies. Well 1-MW7D is 6 to 8 feet north of 1-MW7.	WELL SUMMARY Total depth = 22.5' Screen = 7.5-22.5' Sand = 5.5-22.5' Bentonite = 3.5-5.5' Grout = 0-3.5' Water table elevation not recorded during RFI drilling.
5.0						
10.0						
15.0						
20.0						

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CH2M HILL

PROJECT NUMBER HR020368.KC.02 | **BORING NUMBER** 1-MW7D | SHEET 1 OF 2

SOIL BORING LOG

PROJECT NAS Oceana RFI **LOCATION** West side of North-South ditch
ELEVATION 17.3 feet (Ground) **DRILLING CONTRACTOR** Hardin-Huber, Inc.
DRILLING METHOD AND EQUIPMENT B-53 ATU with 6 1/4 HSA
WATER LEVELS 10.7 feet 1/26/93 **START** 12/18/92 **FINISH** 12/22/92 **LOGGER** S. Brown

DEPTH BELOW SURFACE (FT)	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	COMMENTS
	INTERVAL	TYPE AND NUMBER	RECOVERY (FT)	6"-6"-6" (N)	SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	DEPTH OF CASING, DRILLING RATE DRILLING FLUID LOSS TESTS AND INSTRUMENTATION
.0	2	SS-1	1.0	2-2-2-3 (4)	0-0.7 SANDY SILT (ML), dark yellowish brown (10 YR 4/2), loose, moist; 0.7-0.9 WELL GRADED SAND (SP), grayish orange (10 YR 7/4), loose, dry; 0.9-1.0 same as 0-0.7.	Breathing Zone (BZ) = Background (BG)
	3					
5.0	5	SS-2	1.7	2-4-4-5 (8)	SANDY SILT (ML)/SILTY SAND (SM), pale yellowish brown (10 YR 6/2), loose, moist, sand is very fine, almost silt size.	BZ=BG
	8					Water table at approximately 9.5'.
10.0	10	SS-3	1.2	11-15-26-24 (41)	WELL GRADED SAND (SW), pale yellowish orange (10 YR 8/6), dense, dry at top, wet at the bottom, sand is fine to coarse.	BZ=BG Borehole (BH) = BG
	13					
15.0	15	SS-4	2.0	8-12-18-28 (30)	WELL GRADED SAND (SW), medium light gray (N6), dense, wet, sand is medium to coarse, well-rounded.	BZ=BG BH=BG
	18					
20.0	20	SS-5	2.0	1-1/12-1	SILTY SAND (SM)/POORLY GRADED SAND WITH SILT (SP-SM); dark greenish gray (5 GY 4/1), very loose, wet, sand is very fine.	BZ=BG BH=BG
	23					
25.0	25	SS-6	2.0	1-2-1-4 (3)	Same as SS-5, no shells.	BZ=BG BH=BG
	28					Shells
	30	SS-7		2-7-4-8 (11)	POORLY GRADED SAND WITH SILT (SP-SM), greenish black (5 G 2/1), loose, wet, sand is very fine, trace shells.	BZ=BG BH= 3 ppm

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CH2M HILL

PROJECT NUMBER	BORING NUMBER
HR020368.K0.02	1-MW7D

SHEET 2 OF 2

SOIL BORING LOG

PROJECT NAS Oceana RFI LOCATION West side of North-South ditch

ELEVATION 17.3 feet (Ground) DRILLING CONTRACTOR Hardin-Huber, Inc.

DRILLING METHOD AND EQUIPMENT B-53 ATU with 6 1/4 HSA

WATER LEVELS 10.7 feet 1/26/93 START 12/18/92 FINISH 12/22/92 LOGGER S. Brown

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE DRILLING FLUID LOSS TESTS AND INSTRUMENTATION
30.0						
	33					
35.0	35	SS-8	2.0	8-9-11-13 (20)	POORLY GRADED SAND (SP), greenish black (5 G 2/1), medium density, wet, ~3% fines, sand is very fine, 3% fine shell hash.	BZ=BG BH= 6 ppm
	38					
40.0	40	SS-9	2.0	3-1-1-2 (2)	POORLY GRADED SAND (SP), same as SS-8.	BZ=BG BH= 1 ppm
	43					
45.0	45	SS-10	2.0	2-2-2-5 (4)	POORLY GRADED SAND (SP)/POORLY GRADED SAND WITH SILT (SP-SM), dark greenish gray (5 G 4/1), loose, wet, sand is very fine, shells are 3-4 mm bivalves.	BZ=BG BH= 1 ppm
	48					
50.0	50	SS-11	2.0	2-3-3-3 (6)	POORLY GRADED SAND WITH SILT (SP-SM), dark greenish gray (5 G 4/1), loose, wet, sand is very fine, trace small shell bits.	BZ=BG BH= 4 ppm
	51					
	53	SS-12	2.0	3-3-4-5 (7)	POORLY GRADED SAND WITH SILT (SP-SM), dark greenish gray (5 G 4/1), loose, wet, sand is very fine to fine, 3% shell fragments, some of bivalves of 40 mm size.	BZ=BG BH= 0.5 ppm
55.0	55	SS-13	2.0	4-4-5-6 (9)	POORLY GRADED SAND WITH SILT (SP-SM), same as SS-12.	BZ=BG
	57	SS-14	2.0	2-3-5-4 (8)	POORLY GRADED SAND WITH SILT (SP-SM)/SILTY SAND (SM), dark greenish gray (5 G 4/1), loose, wet, abundant (4%) oyster shells at bottom.	BZ=BG BH= 95 ppm just after removing a cap.
					End of Boring @ 57'.	WELL SUMMARY Total depth = 57' Screen = 45-55' Sand = 42.3-55' Bentonite = 39.5-42.3' Grout = 0-39.5'

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CH2M HILL

PROJECT NUMBER	BORING NUMBER	
HR020368.K0.02	1-MW8	SHEET 1 OF 1

SOIL BORING LOG

PROJECT NAS Oceana RFI LOCATION East of ditch, Northwest corner

ELEVATION 15.2 feet (Ground) DRILLING CONTRACTOR Hardin-Huber, Inc.

DRILLING METHOD AND EQUIPMENT B-53 ATU with 6 1/4 HSA

WATER LEVELS 8.9 feet 1/26/93 START 1/7/93 FINISH 1/7/93 LOGGER S. Brown

DEPTH BELOW SURFACE (FT)	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	COMMENTS
	INTERVAL	TYPE AND NUMBER	RECOVERY (FT)	6"-6"-6" (N)	SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	DEPTH OF CASING, DRILLING RATE DRILLING FLUID LOSS TESTS AND INSTRUMENTATION
0					Refer to Boring 1-MW8D for lithologies.	WELL SUMMARY Total depth = 22' Screen = 7-22' Sand = 4.5-22' Bentonite = 2.5-4.5' Grout = 0-2.5' Water table elevation not recorded during RFI drilling.
5.0						
10.0						
15.0						
20.0						

CH2M HILL

PROJECT NUMBER	BORING NUMBER
HR020368.KO.02	1-MW8D SHEET 1 OF 2

SOIL BORING LOG

PROJECT NAS Oceana RFI LOCATION East of ditch, Northwest corner

ELEVATION 15.4 feet (Ground) DRILLING CONTRACTOR Hardin-Huber, Inc.

DRILLING METHOD AND EQUIPMENT B-53 ATU with 4 1/4 and 6 1/4 HSA

WATER LEVELS 10.6 feet 1/26/93 START 1/5/93 FINISH 1/6/93 LOGGER S. Brown

DEPTH BELOW SURFACE (FT)	SAMPLE: INTERVAL	SAMPLE: TYPE AND NUMBER	SAMPLE: RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE DRILLING FLUID LOSS TESTS AND INSTRUMENTATION
0	3					WELL SUMMARY Total depth = 57' Screen = 42-52' Sand = 39-52' Bentonite = 38-39' Grout = 0-34'
5.0	5	SS-1	1.8	3-4-8-11 (12)	0-1.2 SILT (ML)/LEAN CLAY (CL), brownish gray (5 YR 4/1), stiff, moist; 1.2-1.8' POORLY GRADED SAND (SP), very pale orange (10 YR 8/2), medium density, dry, no odor.	Borehole (BH)= Background (BG), Breathing Zone (BZ) = BG Water table at approximately 5-8'.
	8					
10.0	10	SS-2	1.6	9-10-17-15 (27)	WELL GRADED SAND (SW), very light gray (N8), dense, wet, sand is medium to very coarse, has odor, well-rounded.	BZ=BG BH=BG Jar headspace = 30 ppm
	13					
15.0	15	SS-3	1.8	10-20-32-19 (52)	WELL GRADED SAND (SW), same as SS-2 but some fine sand present, minimal odor.	BZ=BG BH= 25 ppm OVA, BG on Explosimeter Jar headspace = 1 ppm
	18					
20.0	20	SS-4	2.0	5-6-6-9 (12)	0-0.2' LEAN CLAY (CL), olive gray (5 Y 4/1), soft, wet, 0.2-2.0' POORLY GRADED SAND (SP), olive gray (5 Y 4/1), medium density, wet, sand is fine with trace silt sand is well-rounded.	BZ=BG
	23					
25.0	25	SS-5	2.0	5-3-2-4 (5)	Mix of SILTY SAND (SM) and POORLY GRADED SAND WITH SILT (SP-SM), dark greenish gray (5 GY 4/1), loose, wet, very minor shell bits,<1%, 1-2 mm diameter.	Shells BZ=BG BH= 25 ppm Jar headspace = 10 ppm
	28					
30.0	30	SS-6	1.2	2-4-6-10 (10)	POORLY GRADED SAND WITH SILT (SP-SM), same as SS-5 but less silty, 1% shell bits of 1-2 mm diameter.	BZ=BG
	33					

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CH2M HILL

PROJECT NUMBER	BORING NUMBER	
HR020368.K0.02	1-MW8D	SHEET 2 OF 2

SOIL BORING LOG

PROJECT NAS Oceana RFI **LOCATION** East of ditch, Northwest corner

ELEVATION 15.4 feet (Ground) **DRILLING CONTRACTOR** Hardin-Huber, Inc.

DRILLING METHOD AND EQUIPMENT B-53 ATU with 4 1/4 and 6 1/4 HSA

WATER LEVELS 10.6 feet 1/26/93 **START** 1/5/93 **FINISH** 1/6/93 **LOGGER** S. Brown

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE DRILLING FLUID LOSS TESTS AND INSTRUMENTATION
33.0	33–35	SS-7	1.8	5-8-10-21 (18)	0-1.2' Same as SS-6, POORLY GRADED SAND WITH SILT (SP-SM); 1.2-1.8' WELL GRADED SAND WITH GRAVEL (SW), light olive gray (5 Y 6/1), dense, sand is coarse sand to 3 mm gravel, contains large (40 mm) bivalve shell pieces.	BZ=BG BH= 0.5 ppm
35.0						
40.0	38–40	SS-8	2.0	4-2-4-4 (6)	POORLY GRADED SAND WITH SILT (SP-SM), dark greenish gray (5 GY 4/1), loose, wet, mix of razor clam shells, 3 mm bivalves and 40-50 mm bivalve pieces 3% shells, 5% gravel of 4-8 mm diameter.	BZ=BG BH= 1 ppm
45.0	43–45	SS-9	1.7	2-2-4-6 (6)	POORLY GRADED SAND WITH SILT (SP-SM), dark greenish gray (5 GY 4/1), very loose to loose, wet, contains 3% small bivalve shells and shell pieces, sand is very fine to fine, 5-10% fines.	BZ=BG BH= 6 ppm
50.0	48–50	SS-10	2.0	1-2-3-5 (5)	POORLY GRADED SAND WITH SILT (SP-SM), like SS-9 but siltier (10%), 2% mixed shells.	BZ=BG BH= 100 ppm
55.0	53–55	SS-11	2.0	2-4-7-9 (11)	SILTY SAND (SM), dark greenish gray (5 GY 4/1), loose to medium, wet, no shells.	BZ=BG BH= 40 ppm
60.0	58–60	SS-12	2.0	1-8-5-5 (13)	VERY SILTY SAND (SM), almost a sandy silt, dark greenish gray (5 GY 4/1), loose to medium, wet to moist, 1% small bivalves.	BZ=BG BH= 60 ppm
65.0	63–65	SS-13	2.0	1-6-6-5 (12)	SANDY SILT (ML), dark greenish gray (5 GY 4/1), stiff, moist, contains orange brown bivalve shells.	BZ=BG BH= 10 ppm
					End of Boring @ 65'.	

CH2M HILL

PROJECT NUMBER	BORING NUMBER	
HRO20368.KO.02	1-MW9D	SHEET 1 OF 2

SOIL BORING LOG

PROJECT NAS Oceana RFI **LOCATION** Along access road to Site 1

ELEVATION 15.3 feet (Ground) **DRILLING CONTRACTOR** Hardin-Huber, Inc.

DRILLING METHOD AND EQUIPMENT B-53 ATU with 4 1/4 and 8 1/4 HSA

WATER LEVELS 11.4 feet 1/26/93 **START** 12/22/92 **FINISH** 1/5/93 **LOGGER** S. Brown

DEPTH BELOW SURFACE (FT)	SAMPLE: INTERVAL	SAMPLE: TYPE AND NUMBER	SAMPLE: RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE DRILLING FLUID LOSS TESTS AND INSTRUMENTATION
0	3					WELL SUMMARY Total depth = 65' Screen = 50-60' Sand = 46-60' Bentoninte Pellets = 45-46' Bentonite Slurry = 42-45' Grout = 0-42'
5.0	5	SS-1	2.0	3-2-4-6 (6)	0-1' SILT (SM)/LEAN CLAY (CL) dark yellowish brown (10YR 4/2), firm moist. 1-2' POORLY GRADED SAND (SP), very pale orange (10YR 6/2), loose, moist, trace silt (2%), sand is fine.	Breathing Zone (BZ) = Background (BG) Borehole (BH) = BG
	8					Water table at approximately 7'.
10.0	10	SS-2	1.7	5-2-7-9 (9)	WELL GRADED SAND (SW), medium gray (N5), medium density, wet, sand is medium to very coarse.	BZ=BG
	13					
15.0	15	SS-3	2.0	17-21-24-22 (45)	POORLY GRADED SAND (SP), medium light gray (N6), dense to very dense, wet is fine/medium size.	BZ=BG
	18					
20.0	20	SS-4	1.5	6-4-4-4 (8)	POORLY GRADED SAND (SP), olive gray (5Y 4/1), loose, wet, sand is very fine, two 1-inch silt zones.	BZ=BG
	23					
25.0	25	SS-5	1.4	7-4-3-3 (7)	SILTY SAND (SM), dark greenish gray (5 G 4/1), loose, wet, fine shell hash in bottom 8 inches (~1 or 2 % of volume).	BZ=BG BH=BG Shells
	28					
30.0	30	SS-6	1.3	7-11-10-7 (21)	POORLY GRADED SAND WITH SILT (SP-SM), dark greenish gray (5 GY 4/1), medium density, wet, sand is very fine, 1 % fine shell fragments.	BZ=BG
	33					

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CH2M HILL

PROJECT NUMBER	BORING NUMBER
HRO20368.KO.02	1-MW9D — SHEET 2 OF 2

SOIL BORING LOG

PROJECT NAS Oceana RFI LOCATION Along access road to Site 1

ELEVATION 15.3 feet (Ground) DRILLING CONTRACTOR Hardin-Huber, Inc.

DRILLING METHOD AND EQUIPMENT B-53 ATU with 4 1/4 and 8 1/4 HSA

WATER LEVELS 11.4 feet 1/26/93 START 12/22/92 FINISH 1/5/93 LOGGER S. Brown

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE DRILLING FLUID LOSS TESTS AND INSTRUMENTATION
33.0	33–35	SS-7	1.2	9-10-7-7 (17)	POORLY GRADED SAND WITH SILT (SP-SM), same as SS-6.	BZ=BG BH= 3 ppm (after pulling spoon)
35.0						
	38–40	SS-8	2.0	1-2-2-3 (4)	Borderline SILTY SAND (SM)/POORLY GRADED SAND WITH SILT (SP-SM), dark greenish gray (5 GY 4/1), very loose to loose, wet, contains razor clam shells (1%).	BZ=BG BH= 2 ppm
40.0						
	43–45	SS-9	1.8	3-3-4-4 (7)	POORLY GRADED SAND WITH SILT (SP-SM), dark greenish gray (5 GY 4/1), loose, wet contains abundant large bivalves, 5-6% of volume, whole shells would be 30-50 mm.	BZ=BG BH= 0.5 ppm
45.0						
	48–50	SS-10	2.0	WOH/12-4-3 (4)	POORLY GRADED SAND WITH SILT (SP-SM), same as SS-9 but very loose, mix of razor clams and normal oblong clams.	BZ=BG
50.0						
	53–55	SS-11	2.0	1-2-3-5 (5)	SILTY SAND (SM), dark greenish gray (5 GY 4/1), very loose to loose, wet, contains shells.	BZ=BG BH= 1.5 ppm
55.0						
	58–60	SS-12	2.0	4-5-5-5 (10)	VERY SILTY SAND (SM), like SS-11 but siltier, fewer shells.	BZ=BG BH= 10 ppm
60.0						
	63–65	SS-13	2.0	4-3-6-7 (9)	SANDY SILT/SILT WITH SAND (ML), dark greenish gray (5 GY 4/1), stiff, moist, contains small 3-4 min. clam shells.	BZ=BG
65.0					End of Boring @ 65'.	

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CH2M HILL

PROJECT NUMBER	BORING NUMBER	
HRO20368.KO.02	2B-MW1D	SHEET 1 OF 2

SOIL BORING LOG

PROJECT NAS Oceana RFI **LOCATION** At end of Line Shack 131

ELEVATION 21.7 feet (Ground) **DRILLING CONTRACTOR** Hardin-Huber, Inc.

DRILLING METHOD AND EQUIPMENT B-53 ATU with 4 1/4 and 6 1/4 HSA

WATER LEVELS 14.6 feet 2/24/93 **START** 12/7/92 **FINISH** 12/8/92 **LOGGER** S. Brown

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE DRILLING FLUID LOSS TESTS AND INSTRUMENTATION
0					Refer to log for 2B-MW1 for shallow lithologies.	WELL SUMMARY Total depth = 55' Bentonite = 47-50.5' Screen = 36-46' Sand = 33-46' Bentonite = 30.5-33' Grout = 0-30.5' Water table not recorded during RFI drilling.
5.0						
10.0						
15.0					Surface cuttings after drilling to 18 feet are moderate yellowish brown silt and clay.	Surface cuttings after drilling to 18 ft are 150 ppm on OVA.
	18-20	SS-1	1.8	1-1-2-2 (3)	SILTY SAND/SANDY SILT (SM/ML), dark greenish gray (5 GY 4/1), very soft, moist to wet.	Breathing Zone (BZ) = BG
20.0						
	23-25	SS-2	1.2	5-10-12-16 (22)	POORLY GRADED SAND (SP), medium gray (N5), medium density, wet, sand is medium, well-rounded, trace clam shell fragments.	BZ=BG BH=BG
25.0						
	28-30	SS-3	1.8	3-4-1-3 (5)	SILTY SAND/SANDY SILT (SM/ML), dark greenish gray (5 GY 4/1), soft, wet, trace shell fragments of 1-2 mm size, sand is very fine.	BZ=BG BH=BG

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CH2M HILL

PROJECT NUMBER	BORING NUMBER	
HR020368.K0.02	2B-MW1D	SHEET 2 OF 2

SOIL BORING LOG

PROJECT NAS Oceana RFI LOCATION At end of Line Shack 131

ELEVATION 21.7 feet (Ground) DRILLING CONTRACTOR Hardin-Huber, Inc.

DRILLING METHOD AND EQUIPMENT B-53 ATU with 4 1/4 and 6 1/4 HSA

WATER LEVELS 14.6 feet 2/24/93 START 12/7/92 FINISH 12/8/92 LOGGER S. Brown

DEPTH BELOW SURFACE (FT)	SAMPLE: INTERVAL	SAMPLE: TYPE AND NUMBER	SAMPLE: RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE DRILLING FLUID LOSS TESTS AND INSTRUMENTATION
30.0						
	33					
	35	SS-4	2.0	3-5-6-5 (11)	SILTY SAND/SANDY SILT (SM/ML), same as SS-3 but shells <1 % and more sand, sand is very fine.	BZ=BG BH=BG
35.0						
	38					
	40	SS-5	1.0	1-12-10-11 (22)	POORLY GRADED SAND (SP), dark greenish gray (5 GY 4/1), medium density, wet, trace shells (small 3 mm whole bivalves), sand is very fine to fine.	BZ=BG BH=BG
40.0						
	43					
	45	SS-6	1.3	6-20-22-7 (42)	POORLY GRADED SAND (SP), olive gray (5 Y 4/1), dense, wet, 5% large bivalves of >40 mm diameter, sand is medium.	BZ=BG BH=BG
45.0						
	48					
	50	SS-7	2.0	2-3-2-3 (5)	0-1.7 SILTY CLAY (CL), dark greenish gray (5 GY 4/1), firm, moist, no shells; 1.7-2.0 not recorded.	BZ=BG BH=BG
50.0						
	53					
	55	SS-8	2.0	2-3-12-19 (15)	SILTY SAND (SM), same color, medium density, sand is very fine.	BZ=BG BH=BG
55.0					End of Boring @ 55'.	

CH2M HILL

PROJECT NUMBER	BORING NUMBER
HR020368.K0.02	2B-MW5D

SHEET 1 OF 2

SOIL BORING LOG

PROJECT NAS Oceana RFI LOCATION At corner of Site 2B, near MW13 and MW15

ELEVATION 21.8 feet (Ground) DRILLING CONTRACTOR Hardin-Huber, Inc.

DRILLING METHOD AND EQUIPMENT B-53 ATU with 4 1/4 and 6 1/4 HSA

WATER LEVELS 14.4 feet 2/24/93 START 12/9/92 FINISH 12/10/92 LOGGER S. Brown

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE DRILLING FLUID LOSS TESTS AND INSTRUMENTATION
0					Refer to 2b-MW5 well log for shallow lithologies.	WELL SUMMARY Total depth = 51' Screen = 37'-47' Sand = 34'-47' Bentonite = 32'-34' Grout = 0-32'
5.0						Water table elevation not recorded during RFI drilling.
10.0						
15.0						
	16–18	SS-1	1.7	2-2-1-1 (3)	0-1.0' POORLY GRADED SAND WITH SILT (SP-SM), dark greenish gray (5 GY 4/1), very loose, wet, sand is very fine to fine; 1.0-1.7': Like 0-1.0 but SILTY SAND (SM).	BZ=BG BH= 25 ppm
20.0	18–20	SS-2	1.5	2-1-1-1 (2)	POORLY GRADED SAND WITH TRACE SILT (SP) to POORLY GRADED SAND WITH SILT (SP-SM), greenish olive gray (5 Y 4/1), very loose, wet, sand is medium, well-rounded.	BZ=BG BH= 10 ppm
	20–23					
25.0	23–25	SS-3	1.4	5-7-5-20 (12)	WELL GRADED SAND (SW), medium olive gray (5 Y 5/1), medium density, wet, loose sand is very fine to medium from 0-0.9, medium to very coarse 0.9 to 1.4.	BZ=BG BH= 55 ppm
	25–27	SS-4	1.0	15-16-18-21 (34)	WELL GRADED SAND (SW), light olive gray (5 Y 6/1), dense, wet, sand is medium to coarse with some very coarse well rounded rock fragments, trace shells <1%.	BZ=BG BH= 140 ppm
	27–29	SS-5	1.3	1-3-1-3 (4)	SILTY SAND (SM) to SAND WITH SILT (SP-SM), dark greenish gray (5 GY 4/1), very loose to loose, wet, sand is very fine, contains minor shells (0-3%)	BZ=BG BH= 35 ppm

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CH2M HILL

PROJECT NUMBER	BORING NUMBER
HR020368.K0.02	2B-MW5D

SHEET 2 OF 2

SOIL BORING LOG

PROJECT NAS Oceana RFI LOCATION At corner of Site 2B, near MW13 and MW15

ELEVATION 21.8 feet (Ground) DRILLING CONTRACTOR Hardin-Huber, Inc.

DRILLING METHOD AND EQUIPMENT B-53 ATU with 4 1/4 and 6 1/4 HSA

WATER LEVELS 14.4 feet 2/24/93 START 12/9/92 FINISH 12/10/92 LOGGER S. Brown

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE DRILLING FLUID LOSS TESTS AND INSTRUMENTATION
30.0						
	33					
35.0	35	SS-5	2.0	4-3-6-10 (9)	SILTY SAND (SM) to SANDY SILT (ML), greenish black (5 GY 2/1), loose, wet, sand is very fine, borderline with silt, trace small shells.	BZ=BG BH= 200 ppm
	38					
40.0	40	SS-6	2.0	7-16-25-29 (41)	POORLY GRADED SAND (SP), dark greenish gray (5 GY 4/1), dense, wet, 1% small shells and shell bits, trace silt.	BZ=BG BH = 300 ppm
	43					
45.0	45	SS-7	2.0	22-31-24-18 (55)	POORLY GRADED SAND (SP), medium gray (N5), dense to very dense, wet, sand is medium to coarse, well-rounded, contains large bivalve (clam) shells.	BZ=BG
	47	SS-8	2.0	7-2-2-3 (4)	0-0.5' SILTY SAND (SM), olive gray (5 Y 4/1), loose, wet; 0.5-2.0' SANDY SILT (ML), olive gray (5 Y 4/1), very loose, wet, sand is very fine.	BZ=BG BH= 40 ppm
	49	SS-9	1.3	6-7-8-9 (15)	SILTY SAND (SM), olive gray (5 Y 4/1), medium density, wet, sand is very fine.	BZ=BG BH= 75 ppm
50.0	51	SS-10	2.0	5-5-4-4 (9)	0-1.0' SILTY SAND (SM), olive gray (5 Y 4/1), loose, wet, sand is very fine; 1.0-2.0' SANDY SILT (SP-SM), with bands of SILT (SM), loose, wet, sand is very fine.	BZ=BG
					End of Boring @ 51'.	
55.0						

OC-00175-03.13-12/01/93

CH2M HILL

PROJECT NUMBER	BORING NUMBER
HBC20368.K0.02	2B-MW12 SHEET 1 OF 1

SOIL BORING LOG

PROJECT: NAS Oceana RFI
LOCATION: North edge of road to meadow, near MW8
ELEVATION: 18.4 feet (Ground)
DRILLING CONTRACTOR: Hardin-Huber, Inc.
DRILLING METHOD AND EQUIPMENT: B-53 ATU with 6 1/4 HSA
WATER LEVELS: 14.3 feet 2/24/93
START: 12/4/92
FINISH: 12/4/92
LOGGER: S. Brown

DEPTH BELOW SURFACE (FT)	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	COMMENTS
	INTERVAL	TYPE AND NUMBER	RECOVERY (FT)	6"-6"-6" (N)	SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	DEPTH OF CASING, DRILLING RATE DRILLING FLUID LOSS TESTS AND INSTRUMENTATION
0	2	SS-1	0.6	2-3-4-3 (7)	SILT (ML), grayish brown (5 YR 3/2), soften to firm, moist.	WELL SUMMARY Total depth = 22.5' Screen = 12.5-22.5' Sand = 10-22.5' Bentonite = 8-10' Grout = 0-8'
	4					
5.0	6	SS-2	2.0	3-4-12-14 (16)	0-0.9" SILT (ML), same as SS-1. 0.9-2.0 POORLY GRADED SAND (SP), pale yellowish brown (10 YR 6/2), medium density, moist, sand is fine, well-rounded,. trace silt.	Breathing Zone (BZ) = Background (BG)
	9					Water table at approximately 7'.
10.0	11	SS-3	1.8	3-1-1-1 (2)	0-0.9" POORLY GRADED SAND (SP), dark greenish gray (5 GY 4/1), very loose, wet, sand is fine, about 4% silt, 0.9-1.8" SILT (ML) to LEAN CLAY (CL), same color, very soft, wet.	BZ=BG Borehole (BH) = BG
	14					
15.0	16	SS-4	0.9	3-4-1-1 (5)	POORLY GRADED SAND (SP), olive gray (5 Y 4/1), loose, wet. Top 0.7 ft are medium sand, bottom 0.2' is very fine to fine sand.	BZ=BG BH=BG
	19					
20.0	21	SS-5	1.1	8-12-10-10 (22)	POORLY GRADED SAND (SP), olive gray (5 Y 4/1), medium density, wet, sand is medium, well-rounded.	BZ=BG BH=BG
					End of Boring @ 22.6'.	

CH2M HILL

PROJECT NUMBER	BORING NUMBER	
HR020368.K0.02	2B-MW13	SHEET 1 OF 1

SOIL BORING LOG

PROJECT Oceana NAS, RFI LOCATION SWMU 2B-Line Shack 131 Oil Disposal Area

ELEVATION 17.9 feet (Ground) DRILLING CONTRACTOR Hardin-Huber, Inc.

DRILLING METHOD AND EQUIPMENT 6 1/4" ID Hollow Stem Augers/B-80

WATER LEVELS 14.4 feet 2/24/93 START 12-4-92 FINISH 12-4-92 LOGGER D. Braccia

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE DRILLING FLUID LOSS TESTS AND INSTRUMENTATION
0	2	1	1.0	3-3-5-5 (8)	8" LEAN CLAY (CL), dusky yellowish brown (10 YR 2/2) soft consistency moist. 4" FAT CLAY (CL), dark yellowish brown (10 YR 4/2), soft consistency moist.	
	4	2	1.3	4-4-6-8 (10)	14" FAT CLAY (CL), same as above. 2" SAND WITH SILT to SILTY SAND (SP-SM), medium light gray (N6), loose density, wet, trace gravel.	This clay has 1 cm spots scattered throughout that are light brown (5 YR 5/6).
	5					Water table at approximately 4.5'.
5.0	7	3	1.8	8-12-11-11 (23)	SILTY SAND (SM), medium light gray (N6), medium density, wet.	Medium sand grains grade into coarser grains with a trace gravel at the bottom of the split spoon.
	10					
10.0	12	4	1.5	3-9-8-5 (17)	POORLY GRADED SAND (SP), medium dark gray (N4), loose density, wet.	
	15					
15.0	17	5	1.6	1-1-2-5 (3)	7" POORLY GRADED SAND (SP), same as above. 12" WELL-GRADED SAND (SW), medium dark gray (N4), very loose density, wet, grains range from medium to very coarse with trace gravel.	
					End of Boring @ 17'.	
20.0						
25.0						

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CH2M HILL

PROJECT NUMBER	BORING NUMBER
HR020368.K0.02	2B-MW14 SHEET 1 OF 1

SOIL BORING LOG

PROJECT Oceana NAS, RFI LOCATION SWMU 2B-Line Shack 131 Oil Disposal Area

ELEVATION 17.4 feet (Ground) DRILLING CONTRACTOR Hardin-Huber, Inc.

DRILLING METHOD AND EQUIPMENT 6 1/4" ID Hollow Stem Augers/B-80

WATER LEVELS 14.1 feet 2/24/93 START 12-3-92 FINISH 12-4-92 LOGGER D. Braccia

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE DRILLING FLUID LOSS TESTS AND INSTRUMENTATION
.0						
	3–5	1	1.6	3-6-13-18 (19)	6" LEAN CLAY (CL), dusky yellowish brown (10 YR 2/2) soft consistency moist. 14" POORLY GRADED SAND (SP), medium light gray (N6) to dark yellowish orange (10 YR 6/6), loose to medium density, moist to wet.	(SP) has medium grain sizes, and an area of mottling between (10 YR 6/6) and (N6). Water table at approximately 4.5'.
5.0						
	8–10	2	1.9	2-6-6-7 (12)	POORLY GRADED SAND (SP), medium gray (N5), loose density, wet.	
10.0						
	13–15	3	1.4	2-2-2-2 (4)	9" POORLY GRADED SAND (SP), same as above. 8" SANDY SILT (ML), medium dark gray (N4) to medium gray (N5), soft consistency, wet.	
15.0						
	18–20	4	1.25	3-6-10-17 (16)	POORLY GRADED SAND (SP), same as above.	There is a 2" band in this spoon of SANDY SILT (ML), (10 YR 2/2).
20.0					End of Boring @ 20'.	
25.0						

CH2M HILL

PROJECT NUMBER	BORING NUMBER	
HR020368.K0.02	2B-MW15	SHEET 1 OF 1

SOIL BORING LOG

PROJECT NAS Oceana RFI **LOCATION** Adjacent to new training building

ELEVATION 19.0 feet (Ground) **DRILLING CONTRACTOR** Hardin-Huber, Inc.

DRILLING METHOD AND EQUIPMENT B-53 ATU with 6 1/4 HSA

WATER LEVELS 14.3 feet 2/24/93 **START** 12/3/92 **FINISH** 12/4/92 **LOGGER** S. Brown, D. Dronfield

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
0	2	SS-1	1.4	3-4-4-5 (8)	SILT (ML), dark yellowish brown (10 YR 4/2), w/some fine sand, firm, moist, roots.	WELL SUMMARY Total depth = 22.5' Stickup = 2.5' Screen = 12.5-22.5' Sand = 8-22.5' Bentonite = 6-8' Grout = 0-6'
	3					
	5	SS-2	2.0	3-2-4-4 (6)	0-1.8': SILT, as above, 1.8-2.0': as above but more fine sand, yellow orange streaks (10 YR 6/6).	Breathing Zone (BZ) = Background (BG)
5.0	8					Water table at approximately 7'.
	10	SS-3	1.2	12-8-10-10 (18)	WELL SORTED SAND (SP), medium gray (N5), wet, medium density, sand is medium size.	BZ=BG
10.0	13					
	15	SS-4	2.0	3-5-2-2 (7)	Like SS-3 but some finer sand at bottom, loose-medium.	BZ=BG
15.0	18					
	20	SS-5	NR	Not Recorded	Not recorded	BZ=BG Borehole (BH)= 0.5 ppm
20.0					End of Boring @ 22.5'.	

CH2M HILL

PROJECT NUMBER	BORING NUMBER
HR020368.K0.02	2B-MW16 SHEET 1 OF 1

SOIL BORING LOG

PROJECT Oceana NAS, RFI **LOCATION** SWMU 2B-Line Shack 131 Oil Disposal Area

ELEVATION 21.1 feet (Ground) **DRILLING CONTRACTOR** Hardin-Huber, Inc.

DRILLING METHOD AND EQUIPMENT 8 1/4" ID Hollow Stem Augers/B-80

WATER LEVELS 14.6 feet 2/24/93 **START** 12-7-92 **FINISH** 12-8-92 **LOGGER** D. Braccia

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE DRILLING FLUID LOSS TESTS AND INSTRUMENTATION
0						
5.0	3–5	1	0.75	1-2-3-3 (5)	4" FAT CLAY (CH), dusky yellowish brown (10 YR 2/2), soft consistency, moist. 5" SANDY SILT (ML), dark yellow brown (10 YR 4/2), soft consistency, moist.	The SANDY SILT begins to grade into a poorly graded sand with silt. Water table at approximately 5'.
10.0	8–10	2	0.6	2-2-4-10 (6)	WELL-GRADED SAND (SW), medium light gray (N6) to dark yellow orange (10 YR 6/6), loose density, wet, trace silt and gravel.	These two sands grade into each other with a gradual color change over the course of an inch.
15.0	13–15	3	1.6	3-3-10-14 (13)	3" WELL-GRADED SAND (SW), dark yellowish brown (10 YR 4/2), very loose density, wet, trace gravel. 17" POORLY GRADED SAND WITH SILT (SP-SM), medium dark gray (N4), medium density, wet.	
20.0	18–20	4	1.6	2-2-3-5 (5)	WELL-GRADED SAND WITH GRAVEL (SW), medium dark gray (N4), loose density, wet.	
					End of Boring @ 20'.	
25.0						

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CH2M HILL

PROJECT NUMBER	BORING NUMBER	
HB020368.K0.02	2C-MW1D	SHEET 1 OF 3

SOIL BORING LOG

PROJECT NAS Oceana RFI　LOCATION Next to Line Shack 400, wing tank rack

ELEVATION 20.4 feet (Ground)　DRILLING CONTRACTOR Hardin-Huber, Inc.

DRILLING METHOD AND EQUIPMENT B-53 ATU with 4 1/4 and 6 1/4 HSA

WATER LEVELS 13.5 feet 2/23/93　START 12/15/92　FINISH 12/17/92　LOGGER S. Brown

DEPTH BELOW SURFACE (FT)	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	COMMENTS
	INTERVAL	TYPE AND NUMBER	RECOVERY (FT)	6"-6"-6" (N)	SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	DEPTH OF CASING, DRILLING RATE DRILLING FLUID LOSS TESTS AND INSTRUMENTATION
0					Refer to well log for 2C-MW1 for shallow lithologies.	WELL SUMMARY Total depth = 62' Screen = 45-55' Sand = 42-55' Bentonite = 39-42' Grout = 0-39' 6" ID HSA Water table elevation not recorded during RFI drilling.
5.0						
10.0						
15.0						
	18-20	SS-1	2.2	3-5-7-14 (12)	0-1.7' LEAN CLAY (CL), brownish gray (5 YR 4/1), stiff, moist, some small organic matter; 1.7-2.2' POORLY GRADED SAND (SP), olive gray (5 YR 4/1), medium density, wet, sand is very fine to fine, well-rounded.	Breathing Zone (BZ) = Background (BG) Borehole (BH) = 5 ppm
20.0						
	23-25	SS-2	1.8	6-12-15-14 (27)	POORLY GRADED SAND (SP), medium gray (N5), medium density, wet, sand is very fine to fine, trace shell fragments in bottom 8", where sand is very fine, slightly darker 2" clay lens at 24.5'.	BZ= 0-2 ppm. Dissipates withing 30 seconds. BH greather than 1,000 ppm.

CH2M HILL

PROJECT NUMBER	BORING NUMBER
HR020368.K0.02	2C-MW1D SHEET 2 OF 3

SOIL BORING LOG

PROJECT NAS Oceana RFI LOCATION Next to Line Shack 400, wing tank rack
ELEVATION 20.4 feet (Ground) DRILLING CONTRACTOR Hardin-Huber, Inc.
DRILLING METHOD AND EQUIPMENT B-53 ATU with 4 1/4 and 6 1/4 HSA
WATER LEVELS 13.5 feet 2/23/93 START 12/15/92 FINISH 12/17/92 LOGGER S. Brown

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE DRILLING FLUID LOSS TESTS AND INSTRUMENTATION
25.0						
	28–30	SS-3	1.1	7-4-7-7 (12)	POORLY GRADED SAND WITH SILT (SP-SM), olive gray (5 Y 3/2), loose to medium density, wet, sand is extremely fine, about 10% silt, no shells.	BZ=BG BH= 250 ppm
30.0						
	33–35	SS-4	1.0	4-3-7-10 (10)	SILTY SAND (SM), dark greenish gray (5 GY 4/1), loose to medium, wet, trace shell fragments with whole spiral gastropod just like the one found at 27-29' in 2B-MW5D, sand is very fine, silt ~ 20%.	BZ=BG BH= 6 ppm 10 minutes after drilling to sample interval.
35.0						
	38–40	SS-5	2.0	6-20-21-23 (41)	POORLY GRADED SAND (SP), to POORLY GRADED SAND WITH SILT (SP-SM), olive gray, dense, wet. Contains zones of 30% shell hash, large clam shells of 30-40 mm size.	BZ=BG BH= 150 ppm
40.0						
	43–45	SS-6	1.4	9-7-6-4 (13)	POORLY GRADED SAND (SP), olive gray (5 Y 4/1), loose to medium, wet, sand is fine, well-rounded, contains trace shell fragments.	BZ=BG BH= 10 ppm 30 minutes after drilling to sample interval. Considering 7 ft of runup, SS-6 could be out of place.
45.0						
	48–50	SS-7	2.0	4-3-5-4 (8)	0-1.0' POORLY GRADED SAND (SP), like SS-6 but with shells; 1.0-1.5' POORLY GRADED SAND WITH SILT (SP-SM), dark greenish gray (5 GY 4/1), loose, wet; 1.5-2.0' LEAN CLAY (CL) WITH SAND STRINGERS, same color, firm, moist, some shell bits	BZ=BG BH= 4 ppm immediately after drilling.

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CH2M HILL

PROJECT NUMBER HR020368.K0.02

BORING NUMBER 2C-MW1D

SHEET 3 OF 3

SOIL BORING LOG

PROJECT NAS Oceana RFI **LOCATION** Next to Line Shack 400, wing tank rack

ELEVATION 20.4 feet (Ground) **DRILLING CONTRACTOR** Hardin-Huber, Inc.

DRILLING METHOD AND EQUIPMENT B-53 ATU with 4 1/4 and 6 1/4 HSA

WATER LEVELS 13.5 feet 2/23/93 **START** 12/15/92 **FINISH** 12/17/92 **LOGGER** S. Brown

DEPTH BELOW SURFACE (FT)	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	COMMENTS
	INTERVAL	TYPE AND NUMBER	RECOVERY (FT)	6"-6"-6" (N)	SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	DEPTH OF CASING, DRILLING RATE DRILLING FLUID LOSS TESTS AND INSTRUMENTATION
50.0	50–52	SS-8	2.0	2-2-2-3 (4)	Alternating 2-4 inch zones of POORLY GRADED SAND or SAND WITH SILT (SP/SP-SM) and LEAN CLAY WITH SAND STRINGERS (CL), dark greenish gray, very soft to very loose contains shell fragment in both types of sediments.	BZ=BG BH= 10 ppm immediately after drilling.
	52–54	SS-9	2.0	2-3-2-2 (5)	SILTY SAND (SM), dark greenish gray (5 GY 4/1), very loose, wet, sand is very fine to fine, contains shell fragments (<1%).	BZ=BG BH= 35 ppm immediately after sampling.
55.0	54–56	SS-10	2.0	1-2-2-2 (4)	SILTY SAND (SM), dark greenish gray (5 GY 4/1), very loose, wet, contains shell fragments.	BZ=BG
	56–58	SS-11	2.0	3-3-3-3 (6)	SILTY SAND (SM), same as SS-10, but contains two 2-inch zones of sandy lean clay.	BZ=BG BH= 20 ppm
60.0	58–60	SS-12	1.8	3-2-2-2 (4)	0-0.8' SILTY SAND (SM), same as SS-10. 0.8-1.8' LEAN CLAY WITH ABUNDANT SILTY SAND STRINGERS (CL/SM).	BZ=BH BH= 35 ppm Jar headspace = 200 ppm
	60–62	SS-13	2.0	1-2-3-2 (5)	Mix of SANDY SILT (ML), and LEAN SANDY CLAY (CL), dark greenish gray, very loose, wet.	BZ=BG BH= 300 ppm Jar headspace = 450 ppm
					End of Boring @ 62'.	
65.0						
70.0						

CH2M HILL

PROJECT NUMBER	BORING NUMBER	
HR020368.KO.02	2C-MW9D	SHEET 1 OF 3

SOIL BORING LOG

PROJECT NAS Oceana RFI LOCATION In woods across from barracks
ELEVATION 17.1 feet (Ground) DRILLING CONTRACTOR Hardin-Huber, Inc.
DRILLING METHOD AND EQUIPMENT B-53 ATU with 4 1/4 and 6 1/4 HSA
WATER LEVELS 12.8 feet 2/23/93 START 12/11/92 FINISH 12/15/92 LOGGER S. Brown

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE DRILLING FLUID LOSS TESTS AND INSTRUMENTATION
0					Refer to the log for 2C-MW9 for shallow lithologies.	WELL SUMMARY Total depth = 57' Screen = 42-52' Sand = 39-52' Bentonite = 38-39', 34-36' Grout = 0-34' Water table elevation not recorded during RFI drilling.
5.0						
10.0						
15.0						
	18-20	SS-1	1.1	8-15-7-10 (22)	POORLY GRADED SAND (SP), olive gray (5 Y 4/1), medium, wet, sand is fine, well-rounded beach sand.	Breathing Zone (BZ) = background (BG), Borehole (BH) = BG
20.0						
	23-25	SS-2	2.0	4-4-5-6 (9)	POORLY GRADED SAND WITH SILT (SP-SM), dark greenish gray (5 GY 4/1), loose to medium, wet, sand is very fine, contains 1-2% shell hash.	BZ=BG BH= 2 ppm

CH2M HILL

PROJECT NUMBER	BORING NUMBER	
HR020368.K0.02	2C-MW9D	SHEET 2 OF 3

SOIL BORING LOG

PROJECT NAS Oceana RFI LOCATION In woods across from barracks
ELEVATION 17.1 feet (Ground) DRILLING CONTRACTOR Hardin-Huber, Inc.
DRILLING METHOD AND EQUIPMENT B-53 ATU with 4 1/4 and 6 1/4 HSA
WATER LEVELS 12.8 feet 2/23/93 START 12/11/92 FINISH 12/15/92 LOGGER S. Brown

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE DRILLING FLUID LOSS TESTS AND INSTRUMENTATION
25.0						
	28–30	SS-3	1.8	4-2-7-9 (9)	POORLY GRADED SAND/SILT (SP-SM), dark greenish gray (5 GY 4/1), loose to medium, wet, sand is ultra-fine, transitional with silt, contains very minor shell hash of 1 mm size.	BZ=BG BH= 0.5 ppm
30.0						
	33–35	SS-4	2.0	22-36-35-37 (71)	POORLY GRADED SAND (SP), medium light gray (N6), dense to very dense, wet, sand is fine in top 1 foot, fine to medium in bottom 1 foot. Shells and 3 mm bivalves in top ftl, 15-40 mm bivalves (orange tan) in bottom ft.	BZ=BG BH= 10 ppm
35.0						
	38–40	SS-5	2.0	1-2-3-4 (5)	SILTY SAND (SM), dark greenish gray (5 GY 4/1), very loose, wet, sand is very fine, contains 1/2" organic layer in bottom 6", can see leaf veins in layer.	BZ=BG BH= 10 ppm OVA reads 10 ppm on organic zone.
40.0						
	43–45	SS-6	2.0	2-1-2-2 (3)	SILTY SAND (SM)/SANDY SILT (ML), dark greenish gray (6 GY 4/1) very loose, wet, lithology varies from silty sand to sandy silt in 1-3" zones contains minor leaf bits.	BZ=BG
45.0						
	48–50	SS-7	2.0	1-2-3-3 (5)	SANDY SILT (ML), with 1/2 inch LEAN CLAY (CL), zones, olive gray (5 Y 4/1), soft to firm, moist, contains leaf bits.	BZ=BG BH=10 Leaves read 7 ppm on OVA when in spoon. Sample jar headspace = 60 ppm.

CH2M HILL

PROJECT NUMBER	BORING NUMBER
HR020368.K0.02	2C-MW9D SHEET 3 OF 3

SOIL BORING LOG

PROJECT NAS Oceana RFI LOCATION In woods across from barracks

ELEVATION 17.1 feet (Ground) DRILLING CONTRACTOR Hardin-Huber, Inc.

DRILLING METHOD AND EQUIPMENT B-53 ATU with 4 1/4 and 6 1/4 HSA

WATER LEVELS 12.8 feet 2/23/93 START 12/11/92 FINISH 12/15/92 LOGGER S. Brown

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE DRILLING FLUID LOSS TESTS AND INSTRUMENTATION
50.0						
	53					
	55	SS-8	2.0	4-7-9-13 (16)	0-1.0' SILTY SAND (SM), with silt zones, olive gray (5 Y 4/1), medium, wet; 1.0-1.8' LEAN CLAY (CL), same color, very stiff, moist, with leaves; 1.8-2.0' POORLY GRADED SAND WITH SILT LAMELLAE (SP-SM), same color, medium density, wet.	BZ=BG BH= 2 ppm
55.0	57	SS-9	2.0	4-3-4-9 (7)	0-0.8 SILT WITH SAND ZONES (SM), olive gray (5 Y 4/1), firm moist; 0.8-2.0 SILT/LEAN CLAY (SM/CL), olive gray (5 Y 4/1), stiff, moist; (silt predominates 56-57'.)	BZ=BG BH= 30 ppm 56-57' 150 ppm, OVA in jar bent headspace. Headspace of jar containing 56-5 silt/clay = 150 ppm.
					End of Boring @ 57'.	
60.0						
65.0						
70.0						

OC-00175-03.13-12/01/93

CH2M HILL

PROJECT NUMBER	BORING NUMBER	
HR020368.K0.02	2C-MW10	SHEET 1 OF 1

SOIL BORING LOG

PROJECT NAS Oceana RFI **LOCATION** Parking lot across from Building 301

ELEVATION 18.2 feet (Ground) **DRILLING CONTRACTOR** Hardin-Huber, Inc.

DRILLING METHOD AND EQUIPMENT B-53 ATU with 6 1/4 and 8 1/4 HSA/B-80

WATER LEVELS 13.5 feet 2/23/93 **START** 12/10/92 **FINISH** 12/10/92 **LOGGER** D. Braccia

DEPTH BELOW SURFACE (FT)	SAMPLE: INTERVAL	SAMPLE: TYPE AND NUMBER	SAMPLE: RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE DRILLING FLUID LOSS TESTS AND INSTRUMENTATION
0	3					
5.0	3–5	S-1	1.5	2-3-5-10 (8)	15" , FAT CLAY (CH), dark yellowish brown (10 YR 4/2), grades into a light gray (N7) moist, soft consistency, sand <0.5%. 3" POORLY GRADED SAND WITH SILT (SP-SM), light gray (N7), moist, loose density.	OVA = 2 ppm.
	5–7	S-2	1.5	3-6-7-5 (13)	SILTY SAND (SM), light olive gray (5 Y 6/1) to light brown (5 YR 5/6), bottom of spoon grades into a WELL GRADED SAND (SW), wet, loose density, coarse to fine sand.	Water table at approximately 5-7'.
10.0	10					
	10–12	S-3	1.5	2-2-1-3 (3)	14" POORLY GRADED SAND WITH SILT (SP-SM), medium gray to medium dark gray (N4), wet, loose density, muscovite. 4" WELL GRADED SAND (SW), medium light gray (N6) to medium gray (N5), wet, very loose density, muscovite.	
15.0	15					
	15–17	S-4	1.5	5-6-6-8 (12)	WELL GRADED SAND (SW), medium light gray (N6) to medium gray (N5), wet, loose density, trace gravel, very coarse to medium sand.	
20.0	20					
	20–22	S-5	2.0	8-6-4-5 (10)	WELL GRADED SAND (SW), medium light gray (N6) to medium gray (N5), WELL GRADED SAND WITH SILT (SW-SM), medium dark gray (N4).	There was no run-up during drilling. Used a 4" ID HSA.
					End of Boring @ 22'.	

CH2M HILL

PROJECT NUMBER	BORING NUMBER
HR020368.K0.02	2C-MW11 SHEET 1 OF 1

SOIL BORING LOG

PROJECT Oceana NAS, RFI **LOCATION** SWMU 2C-Line Shack 400 Oil Disposal Area

ELEVATION 18.4 feet (Ground) **DRILLING CONTRACTOR** Hardin-Huber, Inc.

DRILLING METHOD AND EQUIPMENT 8 1/4" ID Hollow Stem Augers/B-80

WATER LEVELS 12.5 feet 2/23/93 **START** 12-8-92 **FINISH** 12-9-92 **LOGGER** D. Braccia

DEPTH BELOW SURFACE (FT)	SAMPLE: INTERVAL	SAMPLE: TYPE AND NUMBER	SAMPLE: RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE DRILLING FLUID LOSS TESTS AND INSTRUMENTATION
0	2	1	1.3	5-7-7-9 (14)	SILT (ML), grayish brown (5 YR 3/2) to dusky yellowish brown (10 YR 2/2), firm consistency, dry, trace pebble and organic material.	
	3					
	5	2	1.4	2-3-4-4 (7)	FAT CLAY (CH), dark yellowish brown (10 YR 4/2), soft consistency, moist.	This clay has light brown (5 YR 5/6) mottle marks in it. The bottom 3" of the spoon is the same clay; however, it grades into a light olive gray (5 Y 6/1).
5.0	8					
	10	3	1.8	5-7-7-8 (14)	SILTY SAND (SM), dark gray (N3), loose density, wet. Medium to fine sand grains with some mica.	Water table at approximately 8'.
10.0	13					
	15	4	2.0	6-7-11-11 (18)	WELL-GRADED SAND (SW), medium gray (N5), loose density, wet. Trace gravel and silt.	
15.0	18					
	20	5	2.0	8-10-9-6 (19)	WELL-GRADED SAND (SW), same as above.	
20.0					End of Boring @ 20'.	
25.0						

CH2M HILL

PROJECT NUMBER	BORING NUMBER	
HR020368.K0.02	2C-MW12	SHEET 1 OF 1

SOIL BORING LOG

PROJECT NAS Oceana RFI LOCATION Near barracks door, London Bridge Road

ELEVATION 17.8 feet (Ground) DRILLING CONTRACTOR Hardin-Huber, Inc.

DRILLING METHOD AND EQUIPMENT 6 1/4 and 8 1/4 HSA/B-80

WATER LEVELS 11.7 feet 2/23/93 START 12/9/92 FINISH 12/9/92 LOGGER D. Braccia

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE DRILLING FLUID LOSS TESTS AND INSTRUMENTATION
0	2	S-1	1.1	3-5-5-8 (10)	SANDY SILT (ML), grayish brown (5 YR 3/2) to dusky yellowish brown (10 YR 2/2), moist. The bottom few inches more elastic, grades into FAT CLAY (CH), dark yellowish brown (10 YR 4/2), moist, soft to firm consistency.	OVA = 2 ppm
	3					
5.0	5	S-2	1.0	2-2-5-8 (7)	7" SANDY FAT CLAY (CH), dark yellowish brown (10 YR 4/2) with light brown streaks (5 YR 5/6) and some light gray (N7) areas moist, soft consistency. 5" POORLY GRADED SAND WITH SILT (SP-SM), medium grains, yellowish gray (5 Y 8/1) to light olive gray (5 Y 6/1) to dark yellowish orange (10 YR 6/6), moist, loose density.	
	8					Water table at approximately 6-7'.
10.0	10	S-3	1.5	2-2-2-2 (4)	17" POORLY GRADED SAND WITH SILT (SP-SM), medium dark gray (N4) to dark gray (N3), wet, medium size grains, shell fragments or mica.	
	13					
15.0	15	S-4	1.6	6-8-9-7 (17)	WELL GRADED SAND (SW), medium light gray (N6) to medium gray (N5), wet, loose density, very coarse to coarse sand.	
	18					
20.0	20	S-5	1.3	5-5-10-9 (15)	WELL GRADED SAND (SW), same as above.	
					End of Boring @ 23'.	

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CH2M HILL

PROJECT NUMBER	BORING NUMBER	
HR020368.K0.02	2C-MW13	SHEET 1 OF 1

SOIL BORING LOG

PROJECT NAS Oceana RFI **LOCATION** Near barracks library

ELEVATION 18.4 feet (Ground) **DRILLING CONTRACTOR** Hardin-Huber, Inc.

DRILLING METHOD AND EQUIPMENT 6 1/4 and 8 1/4 HSA/B-80

WATER LEVELS 11.7 feet 2/23/93 **START** 12/11/92 **FINISH** 12/11/92 **LOGGER** D. Braccia

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
0						
5.0	3–5	S-1	1.4	5-6-7-12 (13)	15" FAT CLAY (CH), dark yellowish brown (10 YR 4/2), streaks of dark yellowish orange (10 YR 6/6), moist, firm to stiff consistency. 2" POORLY GRADED SAND WITH SILT (SW-SM), pale yellowish brown (10 YR 6/2), moist, medium density, medium and fine grains.	Water table at approximately 4.5-6'.
10.0	8–10	S-2	1.6	4-5-5-3 (10)	13" POORLY GRADED SAND WITH SILT (SW-SM), medium dark gray (N4), wet, very loose to loose density, medium and fine grains, muscovite fragments. 3" POORLY GRADED SAND (SP), pale yellowish orange (10 YR 8/6) to dark yellowish orange (10 YR 6/6), wet, loose density, medium grains.	
15.0	13–15	S-3	2.0	3-5-8-9 (13)	WELL GRADED SAND (SW), medium light gray (N6) to medium gray (N5), wet, loose density, trace gravel, very coarse to medium, quartz, sand.	
20.0	18–20	S-4	2.0	6-5-4-12 (9)	WELL GRADED SAND (SW), same as above.	
					End of Boring @ 21'.	

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CH2M HILL

PROJECT NUMBER HR020368.K0.02
BORING NUMBER 11-MW2 SHEET 1 OF 1

SOIL BORING LOG

PROJECT Oceana NAS, RFI **LOCATION** SWMU 11-Former Fire Fighting Trainining Pits
ELEVATION 16.6 feet (Ground) **DRILLING CONTRACTOR** Hardin-Huber, Inc.
DRILLING METHOD AND EQUIPMENT 6 1/4" ID Hollow Stem Augers/B-80
WATER LEVELS 12.9 feet 1/25/93 **START** 12-2-92 **FINISH** 12-2-92 **LOGGER** D. Braccia

DEPTH BELOW SURFACE (FT)	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	COMMENTS
	INTERVAL	TYPE AND NUMBER	RECOVERY (FT)	6"-6"-6" (N)	SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	DEPTH OF CASING, DRILLING RATE DRILLING FLUID LOSS TESTS AND INSTRUMENTATION
0	2	1	1.25	7-8-8-6 (16)	SILTY SAND (SM), moderate to dark yellowish brown (10YR4/2), loose density, moist.	This spoon has a 2" band of LEAN CLAY (CL), dusky yellowish brown (10YR2/2).
	5					
5.0	7	2	1.0	2-4-5-7 (9)	SILTY SAND (SM), medium light gray (N6), very loose to loose density, moist.	The grain sizes in this sand are fine to very fine. Water table at approximately 6.5'.
	10					
10.0	12	3	1.75	5-8-13-17 (21)	POORLY GRADED SAND (SP), medium light gray (N6), loose to medium density, wet.	Sand grains are coarse and sub-angular.
	15					
15.0	17	4	2.0	7-8-9-5 (17)	POORLY GRADED SAND (SP), same as above except loose density.	There is a 2" band of ELASTIC SILT WITH SAND (MH), medium gray (N5) with moderate brown (5YR4/4) streaks through it.
	20					
20.0	22	5	2.0	7-9-11-16 (20)	POORLY GRADED SAND (SP), same as above.	
					End of Boring @ 22'.	
25.0						

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CH2M HILL

PROJECT NUMBER	BORING NUMBER
HR020368.K0.02	11-MW3 SHEET 1 OF 1

SOIL BORING LOG

PROJECT Oceana NAS, RFI LOCATION SWMU 11-Former Fire Fighting Trainining Pits

ELEVATION 17.3 feet (Ground) DRILLING CONTRACTOR Hardin-Huber, Inc.

DRILLING METHOD AND EQUIPMENT 6 1/4" ID Hollow Stem Augers/B-80

WATER LEVELS 13.2 feet 1/25/93 START 12-2-92 FINISH 12-3-92 LOGGER D. Braccia

DEPTH BELOW SURFACE (FT)	SAMPLE: INTERVAL	SAMPLE: TYPE AND NUMBER	SAMPLE: RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE DRILLING FLUID LOSS TESTS AND INSTRUMENTATION
0						
	3–5	1	1.6	5-5-4-4 (9)	FAT CLAY (CH), dusky yellowish brown (10 YR 2/2), soft to firm consistency, moist.	
5.0						Water table at approximately 6'.
	8–10	2	1.3	4-5-8-13 (13)	POORLY GRADED SAND (SP), grayish orange (10 YR 7/4) to dark yellowish orange (10 YR 6/6), loose to medium density, wet.	The sand's top portion is a medium bluish gray (5 B 5/1) before becoming th grayish orange to dark yellowish hue.
10.0						
	13–15	3	2.0	7-13-20-34 (33)	WELL-GRADED SAND (SW), light olive gray (5 Y 5/2), medium density, wet.	This sand becomes a POORLY GRADED SAND (SP), medium gray (N5), on the bottom half of this split spoon.
15.0						
	18–20	4	2.0	2-1-1-7 (2)	POORLY GRADED SAND (SP), medium gray (N5), very loose to loose density, wet.	
20.0					End of Boring @ 20'.	
25.0						

OC-00175-03.13-12/01/93

CH2M HILL

PROJECT NUMBER	BORING NUMBER	
HRC20368.K0.02	22-MW1	SHEET 1 OF 1

SOIL BORING LOG

PROJECT NAS Oceana RFI — LOCATION In meadow, upgradient of landfill

ELEVATION 16 feet (Ground) — DRILLING CONTRACTOR Hardin-Huber, Inc.

DRILLING METHOD AND EQUIPMENT B-53 ATU with 6 1/4 and 8 1/4 HSA

WATER LEVELS 12.0 feet 1/26/93 — START 12/15/92 — FINISH 12/15/92 — LOGGER D. Braccia

DEPTH BELOW SURFACE (FT)	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	COMMENTS
	INTERVAL	TYPE AND NUMBER	RECOVERY (FT)	6"-6"-6" (N)	SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	DEPTH OF CASING, DRILLING RATE DRILLING FLUID LOSS TESTS AND INSTRUMENTATION
0	2	S-1	1.6	2-1-4-5 (5)	12" WELL GRADED SAND (SW), moderate yellowish brown (10 YR 3/4) to dark yellowish orange (10 YR 6/6), mosit, very loose, very coarse to medium sand. 10" FAT CLAY (CH), light olive gray (5 Y 6/1), moist, soft consistency.	Within 20' of wetland area.
	3					
5.0	5	S-2	1.5	6-7-9-7 (16)	8" POORLY GRADED SAND WITH SILT (SP-SM), very pale orange (10 YR 8/2), wet, loose density, coarse to medium sand with thin lamerae moderately red (5 R 4/6) to moderate reddish brown (10 R 4/6).	Water table at approximately 4'.
	8					
10.0	10	S-3	1.5	4-6-6-8 (12)	6" POORLY GRADED SAND WITH SILT (SP-SM), medium dark gray (N4), wet, loose density, medium to coarse sand. 12" WELL GRADED SAND (SW), medium gray (N5), wet, loose density, very coarse to medium sand with trace gravel.	
	13					
15.0	15	S-4	1.0	4-3-4-9 (7)	12" POORLY GRADED SAND (SP), medium gray (N5), wet, loose density. Same as above except fewer coarse grains, not as wide a spectrum of grain sizes.	
	18					
20.0	20	S-5	1.6	4-5-10-6 (15)	14" WELL GRADED SAND (SW), medium light gray (N6), medium gray (N5), wet, loose density, medium to coarse sand grading into very coarse to medium sand with trace gravel.	
					End of Boring @ 20'.	

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CH2M HILL

PROJECT NUMBER	BORING NUMBER
HR020368.K0.02	22-MW2 SHEET 1 OF 1

SOIL BORING LOG

PROJECT NAS Oceana RFI **LOCATION** Northern-most well along ditch

ELEVATION 15.6 feet (Ground) **DRILLING CONTRACTOR** Hardin-Huber, Inc.

DRILLING METHOD AND EQUIPMENT B-53 ATU with 6 1/4 and 8 1/4 HSA

WATER LEVELS 8.1 feet 1/26/93 **START** 12/17/92 **FINISH** 12/17/92 **LOGGER** D. Braccia

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE DRILLING FLUID LOSS TESTS AND INSTRUMENTATION
0	2	S-1	1.25	6-7-8-9 (15)	3" POORLY GRADED SAND WITH SILT (SP-SM), light brown (5 YR 5/6), moist, loose density, medium sand. 12" FAT CLAY (CH), yellowish gray (5 Y 7/2), moist, firm consistency, with dark reddish brown (10 R 3/4) grains.	
	3					
5.0	5	S-2	1.1	2-4-9-8 (13)	14" POORLY GRADED SAND (SP), very pale orange (10 YR 8/2), moist, very loose to loose density, 10% SILT, medium to fine sands.	
	8					
10.0	10	S-3	1.3	4-6-8-7 (14)	16" POORLY GRADED SAND (SP), same as above except grayish orange (10 YR 7/4) and very pale orange (10 YR 8/2), wet.	Water table at approximately 8'.
	13					
15.0	15	S-4	1.5	4-6-8-10 (14)	18" POORLY GRADED SAND (SP), very pale orange (10 YR 8/2), moist, very loose to loose density, 10% SILT, medium to fine sands.	
	18					
20.0	20	S-5	1.5	2-3-2-2 (5)	18' WELL GRADED SAND (SW), dark yellowish orange (10 YR 6/6), wet, very loose density, coarse to fine sands.	
					End of Boring @ 23'.	

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CH2M HILL

PROJECT NUMBER	BORING NUMBER	
HR020368.KO.02	22-MW3	SHEET 1 OF 1

SOIL BORING LOG

PROJECT NAS Oceana RFI **LOCATION** Along horse trail

ELEVATION 19.2 feet (Ground) **DRILLING CONTRACTOR** Hardin-Huber, Inc.

DRILLING METHOD AND EQUIPMENT B-53 ATU with 6 1/4 and 8 1/4 HSA

WATER LEVELS 9 feet 1/26/93 **START** 12/16/92 **FINISH** 12/16/92 **LOGGER** D. Braccia

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE DRILLING FLUID LOSS TESTS AND INSTRUMENTATION
0	0–2	S-1	1.6	6-7-5-8 (12)	15" WELL GRADED SAND (SW), very pale orange (10 YR 8/2) to dark yellowish brown (10 YR 4/2) to light brown (5 YR 5/6), moist, loose density, trace gravel in sand with very coarse to medium grain sands. 5" FAT CLAY (CH), light olive gray (5 Y 6/1), moist, firm consistency.	
5.0	5–7	S-2	1.6	8-10-14-16 (24)	20" POORLY GRADED SAND WITH GRAVEL (SP), dark yellowish orange (10 YR 6/6) to very pale orange (10 YR 8/2) moist, medium density, very coarse to coarse with trace gravel and medium sands towards bottom of spoon.	
10.0	10–12	S-3	1.8	6-7-6-6 (13)	6" WELL GRADED SAND WITH GRAVEL (trace) (SW), dark yellowish orange (10 YR 6/6), wet, loose density. 16" POORLY GRADED SAND (SP), very pale orange (10 YR 8/2) to dark yellowish orange (10 YR 6/6), wet, loose density, medium sand.	Water table at approximately 10-13'.
15.0	15–17	S-4	0.6	6-5-4-6 (9)	6" WELL GRADED SAND WITH SILT (SW-SM), medium gray (N5), moist, loose density, trace gravel, silt <5%, trace shell fragments.	
20.0	20–22	S-5	1.6	8-9-13-26 (22)	18" WELL GRADED SAND WITH GRAVEL (trace) (SW), light gray (N7) to medium light gray (N6), wet, loose to medium density, trace shell fragments, very coarse to fine sand.	
					End of Boring @ 22'.	

CH2M HILL

PROJECT NUMBER	BORING NUMBER
HR020368.KO.02	22-MW4 SHEET 1 OF 1

SOIL BORING LOG

PROJECT NAS Oceana RFI **LOCATION** Along horse trail, closest to airfield

ELEVATION 16.6 feet (Ground) **DRILLING CONTRACTOR** Hardin-Huber, Inc.

DRILLING METHOD AND EQUIPMENT B-53 ATU with 6 1/4 and 8 1/4 HSA

WATER LEVELS 10.2 feet 1/26/93 **START** 12/17/92 **FINISH** 12/17/92 **LOGGER** D. Braccia

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE DRILLING FLUID LOSS TESTS AND INSTRUMENTATION
0	2	S-1	1.3	1-1-5-6 (6)	7" SANDY SILT (ML), dark yellowish brown (10 YR 4/2), moist, very soft to soft consistency, fine to medium sand. 9" FAT CLAY (CH), yellowish gray (5 Y 7/2), moist, firm consistency, light brown mottled marks, quarter size (5 YR 5/6).	
	3					
	5	S-2	1.3	5-10-11-13 (22)	15" POORLY GRADED SAND (SP), dark yellowish orange (10 YR 6/6) to grayish orange (10 YR 9/4), moist, loose to medium density, 2" section of gravel.	
5.0	8					
	10	S-3	0.5	1-2-7-9 (9)	WELL GRADED SAND WITH SILT (SW-SM), grayish orange (10 YR 7/4) to dark yellowish orange (10 YR 6/6), wet, loose density.	Water table at approximately 8'.
10.0	13					
	15	S-4	1.0	2-3-3-4 (6)	13" WELL GRADED SAND (SW), medium dark gray (N4), wet, loose density, fine to coarse sands.	
15.0	18					
	20	S-5	1.6	13-18-28-32 (46)	20" WELL GRADED SAND (w/trace gravel) (SW), light gray (N7) to medium light gray (N6), wet, medium density, medium to very coarse and trace gravel.	
20.0					End of Boring @ 20'.	

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PROJECT NUMBER W20368 | 02B-GW1 | SHEET OF

SOIL BORING LOG

PROJECT CONFIRMATION STUDY LOCATION OCEANA

ELEVATION 21.75' DRILLING CONTRACTOR ATEC

DRILLING METHOD AND EQUIPMENT AUGER

WATER LEVEL AND DATE 4/3/86 START FINISH LOGGER PAINTER

ELEVATION	DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOLIC LOG	WELL CONSTRUCTION 2 inch PVC
		0-2	S1	2.0	5-6-7-6	Silty Clay; gray; mod. stiff; mod. plastic		GROUT
	5	4-6	S2	1.7	2-2-3-3			BENTONITE
		9-11	S3	2.0	3-8-12-13	F-M silty sand; gray; wet		SAND
	15	14-16	S4	1.3	1-1-3-5			
	20	19-21	S5	2.0	1-3-5-6	Silty clay; dk gray; plastic; sticky		
						Fine silty sand; gray		
	25							

REV 11/82 FORM D1586

CH2M HILL

PROJECT NUMBER: WDC20368.D0 | BORING NO.: 2B-MW5 | SHEET: 1 OF 1

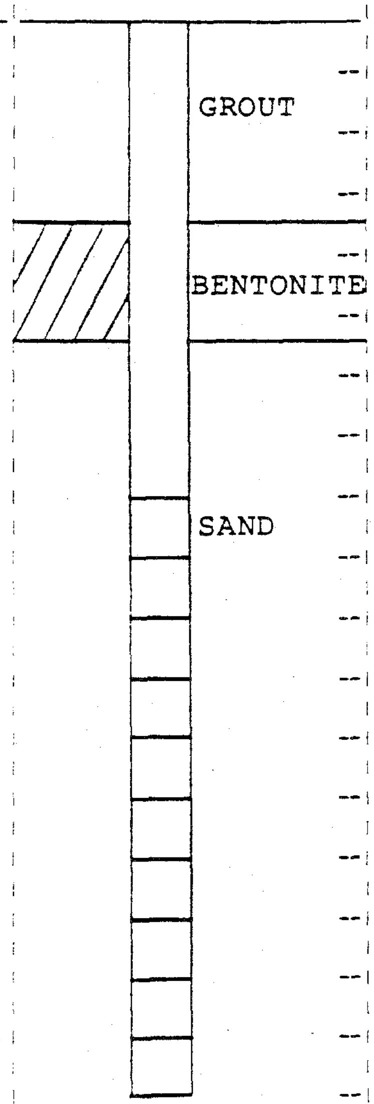
SOIL BORING LOG

PROJECT: LINE SHACK INVESTIGATION | LOCATION: OCEANA
ELEVATION: | DRILLING CONTRACTOR: LAW ENGENEERING
DRILLING METHOD AND EQUIPMENT: CME HSA
WATER LEVEL AND DATE: 7.5', 9/1/88 | START: 9/1/88 | FINISH: 9/1/88 | LOGGER: D. McCRACKIN

DEPTH BELOW SURFACE	DEPTH: INTERVAL	DEPTH: TYPE AND NUMBER	REC	STD. PEN. TEST 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOL LOG
	0-2	S1	16	4-6-3-6 (9)	Silty f. sand, w/ tr. clay and tr. gravel, medium dark gray (N4), moist.	
	3-5	S2	14	4-3-3-3 (6)	Clay, tr. f. sand, dark gray (N3), moist, low plasticity.	
5						
	8-10	S3	24	5-8-10-11 (18)	F. sand, tr. silt and tr. gravel (< 1/8') light gray (N7) saturated.	
10						
	13-15	S4	24	10-10-12-15 (22)	F. sand, tr. silt, medium gray (N5), saturated.	
15						
	18-20	S5	22	7-9-18-10 (27)	M-c. sand, tr. gravel (<1/4"), medium dark gray (N4), saturated.	
20						

WELL CONSTRUCTION

2 inch PVC
FLUSH MOUNT



SBLSYM 06/14/88

OC-00175-03.13-12/01/93

CH2M HILL

PROJECT NUMBER: WDC20368.D0	BORING NO.: 2C-MW1	SHEET: 1 OF 1

SOIL BORING LOG

PROJECT: LINE SHACK INVESTIGATION — LOCATION: OCEANA

ELEVATION: — DRILLING CONTRACTOR: LAW ENGENEERING

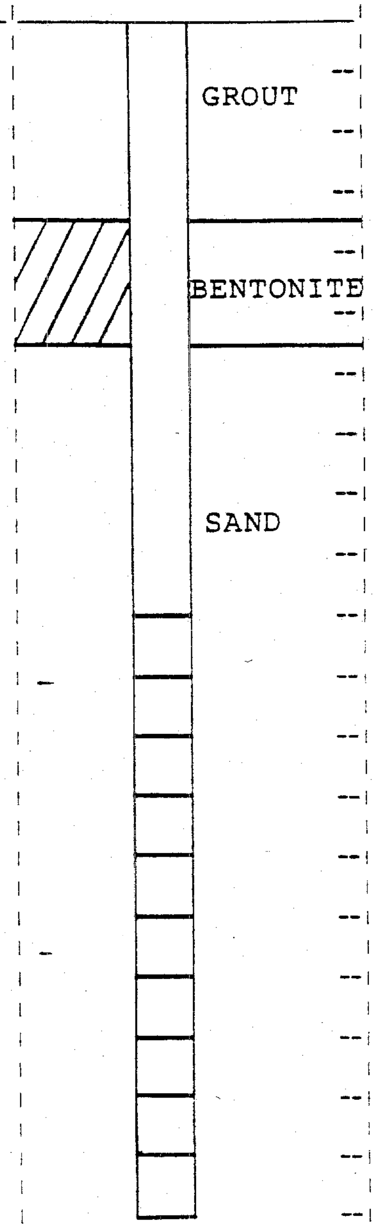
DRILLING METHOD AND EQUIPMENT: CME HSA

WATER LEVEL AND DATE: ~7', 9/13/88 — START: 9/13/88 — FINISH: 9/13/88 — LOGGER: D. McCRACKIN

DEPTH BELOW SURFACE	DEPTH: INTERVAL	DEPTH: TYPE AND NUMBER	DEPTH: REC	STD. PEN. TEST 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOL LOG
	0-2	S1	21	4-11-11-8 (22)	F. sand, pale yel. bronw(10YR6/2), moist.	
	3-5	S2	13	4-2-3-3 (5)	Clay w/ tr. organic material, dusky yel. brown (10YR2/2), moist, low plasticity.	
5						
	8-10	S3	11	9-5-4-5 (9)	Vf-f. sand, medium gray (N5), wet.	
10						
	13-15	S4	24	1-1-1-4 (2)	Clayey silty vf-f. sand, dark gray (N3), wet, low plasticity.	
15						
	18-20	S5	20	5-15-31-50 (46)	Vf-f. sand, tr. silt, medium dark gray (N4), wet.	
20						

WELL CONSTRUCTION

2 inch PVC FLUSH MOUNT



CH2M HILL	PROJECT NUMBER: WDC 20368.H0.03	BORING NO.: 2C-MW9	SHEET: 1 OF 1

SOIL BORING LOG

..ECT: LANTDIV-OCEANA LOCATION: SITE 2C, NEAR PATH IN WOODS
..EVATION: 17.0 DRILLING CONTRACTOR: ATEC (NORFOLK)
DRILLING METHOD AND EQUIPMENT: MOBILE B-53 RIG WITH 4 1/4 AND 6 1/4-INCH HSA
WATER LEVEL AND DATE: START: 7/2/90 FINISH: 7/3/90 LOGGER: STEVEN BROWN

DEPTH BELOW SURFACE	DEPTH: INTERVAL	DEPTH: TYPE AND NUMBER	DEPTH: REC	STD. PEN. TEST 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOL LOG	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TEST AND INSTRUMENTATION
	0-2	S1	14	3-4-4-4	0-14": CLAYEY SILT, brownish gray (5YR 4/1) dry, soft, high organic content at surface		
	3.5-5	S2	18	5-5-9	0-6": SILT, brownish gray (5 YR 4/1), dry, soft; 6-11": SAND, dark yellowish orange (10 YR 6/6), moist, loose; 11-18": SAND, lt. olive gray (5 Y 6/1), moist, loose		
5							
							Water table at approx. 7 to 8 ft.
	8.5-10	S3	18	3-2-3	0-18": SAND, f. to med., med. gray (N6), wet, loose		
10							
	13.5-15	S4	18	8-12-9	0-18": SAND, f. to coarse, med. lt. gray (N6), wet, loose		
15							
							WELL SUMMARY
	16.5-18	S5	18	6-7-6	0-18": SAND, same as S4		
							FINAL DEPTH = 18'
							SCREEN = 7'6" TO 17'6"
							SAND = 4'6" TO 18'
							BENTONITE 3'6" TO 4'6"
							GROUT = 0' TO 3'6"
20							

Appendix D
Environmental Sampling

Appendix D
Environmental Sampling

This appendix includes detailed discussion of various environmental sampling activities such as:

- Groundwater Sampling
- Surface Water and Sediment Sampling
- Soil Sampling
- Quality Assurance Sampling
- Sample Handling
- Decontamination Procedures

A table of field parameter measurements during groundwater sampling is also included.

Groundwater Sampling

As part of this RFI, a total of 55 monitoring wells were sampled from January 18 to February 5, 1993. The monitoring wells that were sampled are found at seven different sites, including Sites 1, 2B, 2C, 2D, 2E, 11, and 22. The results of this groundwater sampling round are presented in tabular form and discussed in Chapter 4. The ensuing paragraphs detail the groundwater sampling procedures followed by CH2M HILL field personnel.

The groundwater sampling program separates into four activities which were repeated at all of the 55 monitoring wells sampled. The four activities which constitute the groundwater sampling program, listed in order of occurrence, are (1) measurement of water levels, (2) purging of water from the monitoring well, (3) sample collection, and (4) decontamination of the sampling pump and equipment.

Prior to purging the water from any well at a given site, the water levels in all wells at that site were recorded to the nearest 0.01 foot using electronic probes. The measurements of static water level elevations were used to calculate water volumes in the well. The water level measurements were later used in conjunction with the surveyed well elevations to calculate groundwater hydraulic gradients and to predict groundwater flow directions and velocities.

Having measured the water levels in the wells, and calculated the well volumes, CH2M HILL personnel purged each well before sampling. Purging, which is the process whereby standing water is removed from the well, allows for sampling of groundwater directly from the aquifer. Free product was discovered in 1-MW4, 1-MW5, and 2E-MW1. The free product's thickness was measured with an electronic interface probe and sampled using a disposable bailer when sufficient quantities were present.

The shallow and deep monitoring wells were purged with a QED positive displacement bladder pump, which was placed in the monitoring well approximately at the top of the screened interval. The pump's discharge was collected in a graduated container for volume measurements. For each well volume purged from the well, the water's pH, specific conductivity, and temperature were recorded using calibrated electronic meters. Sampling occurred after the parameters had stabilized to within 10 percent for three well volumes. During the purging of well volumes, the water level in the wells recovered rapidly; therefore, there were no time lapses between the purging and sample collection. Table D-1 is a summary of parameters measured during groundwater sampling.

After purging was complete, groundwater samples were collected in the sample bottles provided by CH2M HILL's laboratory in Montgomery, Alabama. Each sample bottle came with the required preservative, as appropriate for the type of sample. CH2M HILL personnel collected groundwater samples from all of the monitoring wells using the same QED submersible bladder pump that was used in the purging process. At 1-MW4, the bailer was lowered to the bottom of the well to sample possible DNAPL contamination; however, DNAPL was not present. During sampling, the pump was placed at the top of the screened zone, and the pumping rate was adjusted according to the sample being collected. For instance, when VOC samples were being collected, CH2M HILL field personnel adjusted the pump discharge using valves on the control box to achieve a flow rate low enough to fill the VOC bottles without aerating the sample (approximate flow rate of 100 ml/min). Sample collectors inspected VOC bottles for air bubbles onsite, and recollected the samples if any bubbles were present. Having collected the VOC samples, the pump's flow rate was returned to a normal discharge and the remaining parameters collected. The samples collected for dissolved metals analysis were field-filtered through a disposable 0.45 micron filter prior to preservation. Samples collected for total metals did not require filtration. At 1-MW4, free product was encountered and sampled using a teflon bailer. At 2E-MW1, free product was bailed from the water table prior to groundwater sampling.

Surface Water and Sediment Sampling

Surface water and sediment samples were collected from the perennially flowing ditches at Sites 1, 22, 2B, and 7, and from the former borrow pit at Site 25. At Site 7, only sediment samples were collected in the drainage ditch. The Site 7 sampling was a non-RFI activity done at the request of the Navy and the EPA. Results were communicated in a separate memo. At all sites, CH2M HILL field personnel collected the surface water samples followed by the sediment samples. The CH2M HILL analytical laboratory in Montgomery, Alabama, provided all sample containers and jars, with the appropriate preservatives.

Table D-1
SUMMARY OF PARAMETERS MEASURED DURING GROUNDWATER SAMPLING
NAS OCEANA
1993

Sample Location	Sampled Date	Sampled Time	Approx. Volume of Well (gal)	Approx. Volume of Purge (gal)	Method[1] of Purge/ Sampling	Conductivity (μmho/cm)	Temp (°C)	pH	Comments
01-MW3	01/27/93	1005	2.07	6.21	PQ/PQ	190	14.0	5.59	
01-MW4	01/28/93	1300	2.0	8.0	PQ/PQ	210	16.0	5.78	
01-MW4LN	01/28/93	1205	NM	NM	DB/DB	NM	NM	NM	Free Product LNAPL
01-MW4DN	NT	NT	NT	NT	NT	NT	NT	NT	No DNAPL Present
01-MW5	01/28/93	1545	2.0	8.0	PQ/PQ	230	14.0	5.89	
01-MW6	01/27/93	1510	2.4	9.6	PQ/PQ	260	13.0	6.00	
01-MW7	01/26/93	1630	2.5	7.5	PQ/PQ	415	13.0	6.20	
01-MW7D	01/26/93	1545	7.88	23.94	PQ/PQ	510	13.0	6.69	
01-MW8	01/28/93	0945	2.5	7.5	PQ/PQ	470	14.0	6.68	
01-MW8D	01/28/93	0823	8.0	24.0	PQ/PQ	450	13.0	7.34	
01-MW9D	01/27/93	1150	9.0	27.0	PQ/PQ	450	14.0	6.98	
2B-MW1	01/25/93	1315	2.2	6.6	PQ/PQ	288	13.3	5.72	
2B-MW1D	01/25/93	1210	6.7	20.0	PQ/PQ	255	14.2	7.55	
2B-MW2	01/20/93	1025	3.4	10.5	PQ/PQ	295	13.3	7.22	
2B-MW3	01/20/93	1220	3.3	6.6	PQ/PQ	400	10.0	6.30	Well Pumped Dry
2B-MW4	01/20/93	1515	2.2	8.8	PQ/PQ	480	14.4	6.32	
2B-MW5	01/21/93	0925	2.2	8.8	PQ/PQ	510	14.8	5.98	
2B-MW5D	01/21/93	1100	6.8	20.4	PQ/PQ	330	16.5	7.59	

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Table D-1
SUMMARY OF PARAMETERS MEASURED DURING GROUNDWATER SAMPLING
NAS OCEANA
1993

Sample Location	Sampled		Approx. Volume of Well (gal)	Approx. Volume of Purge (gal)	Method[1] of Purge/ Sampling	Conductivity (μmho/cm)	Temp (°C)	pH	Comments
	Date	Time							
2B-MW6	01/20/93	1640	1.7	5.1	PQ/PQ	190	12.0	4.96	
2B-MW7	01/19/93	1630	2.0	8.0	PQ/PQ	330	12.0	7.19	
2B-MW8	01/20/93	1005	3.1	9.3	PQ/PQ	230	13.0	5.18	
2B-MW9	01/20/93	0845	3.0	9.0	PQ/PQ	420	13.6	6.75	
2B-MW10	01/21/93	0935	2.2	6.6	PQ/PQ	253	14.6	6.51	
2B-MW11	01/21/93	1105	2.06	6.2	PQ/PQ	438	16.6	5.84	
2B-MW12	01/20/93	1140	3.3	16.5	PQ/PQ	320	14.0	6.03	
2B-MW13	01/19/93	1705	3.0	9.0	PQ/PQ	82	12.3	5.66	
2B-MW14	01/20/93	1214	2.8	9.0	PQ/PQ	375	15.5	6.40	
2B-MW15	01/19/93	1515	3.15	9.45	PQ/PQ	360	12.0	7.46	
2B-MW16	01/20/93	1445	2.5	7.5	PQ/PQ	430	16.0	4.65	
2C-MW1	01/25/93	1200	2.4	7.2	PQ/PQ	610	16.0	6.24	
2C-MW1D	01/25/93	1330	8.1	24.3	PQ/PQ	510	17.0	6.97	
2C-MW2	01/21/93	1415	2.4	7.2	PQ/PQ	640	15.2	6.48	
2C-MW3	01/22/93	1055	2.3	7.5	PQ/PQ	490	17.3	5.98	
2C-MW4	01/22/93	1220	2.5	7.5	PQ/PQ	430	17.7	5.97	
2C-MW5	01/22/93	1000	2.0	6.0	PQ/PQ	480	16.0	6.13	
2C-MW6	01/22/93	1050	2.6	7.8	PQ/PQ	330	16.0	5.90	

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Table D-1
SUMMARY OF PARAMETERS MEASURED DURING GROUNDWATER SAMPLING
NAS OCEANA
1993

Sample Location	Sampled Date	Sampled Time	Approx. Volume of Well (gal)	Approx. Volume of Purge (gal)	Method[1] of Purge/ Sampling	Conductivity (μmho/cm)	Temp (°C)	pH	Comments
2C-MW7	01/22/93	0900	2.3	9.2	PQ/PQ	195	19.0	5.98	
2C-MW8	01/21/93	1600	2.2	6.6	PQ/PQ	195	19.0	5.98	
2C-MW9	01/22/93	1215	2.5	7.5	PQ/PQ	300	16.0	5.76	
2C-MW9D	01/22/93	1330	8.0	24.0	PQ/PQ	510	16.0	6.92	
2C-MW10	01/21/93	1600	3.15	9.45	PQ/PQ	540	17.0	6.38	
2C-MW11	01/21/93	1735	3.1	9.3	PQ/PQ	500	16.6	6.57	
2C-MW12	01/22/93	0915	3.1	9.3	PQ/PQ	425	16.8	6.45	
2C-MW13	01/21/93	1430	2.6	7.8	PQ/PQ	420	17.2	6.52	
2D-MW1	01/18/93	1320	2.5	10.0	PQ/PQ	250	15.0	7.63	
2D-MW2	01/25/93	1730	2.34	7.02	PQ/PQ	570	15.4	6.35	
2D-MW3	01/25/93	1600	2.5	7.5	PQ/PQ	190	23.4	6.31	
2E-MW1	02/05/93	1150	3.0	15.0	DB/DB	320	17.7	6.99	Free Product in Well
2E-MW2	01/18/93	1715	2.6	7.8	PQ/PQ	230	15.0	7.63	
2E-MW3	01/18/93	1600	2.6	7.8	PQ/PQ	149	14.0	7.95	
1-MW1	01/26/93	1420	3.0	9.0	PQ/PQ	160	13.0	5.40	
11-MW1	01/25/93	1730	2.5	7.5	PQ/PQ	120	12.0	5.72	
11-MW2	01/26/93	0845	2.75	8.25	PQ/PQ	180	13.0	5.54	
11-MW3	01/25/93	1620	2.65	10.60	PQ/PQ	160	15.0	5.70	

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Table D-1
SUMMARY OF PARAMETERS MEASURED DURING GROUNDWATER SAMPLING
NAS OCEANA
1993

Sample Location	Sampled Date	Sampled Time	Approx. Volume of Well (gal)	Approx. Volume of Purge (gal)	Method[1] of Purge/ Sampling	Conductivity (µmho/cm)	Temp (°C)	pH	Comments
22-MW1	01/26/93	1030	2.6	7.8	PQ/PQ	120	10.3	5.54	
22-MW2	01/26/93	1220	2.6	10.4	PQ/PQ	98	15.8	5.65	
22-MW3	01/27/93	0945	3.0	9.0	PQ/PQ	171	15.1	5.84	
22-MW4	01/27/93	1220	2.75	8.25	PQ/PQ	180	14.9	5.82	

Notes: [1]Method of purge sampling: PQ = Portable QED Well Wizard® Positive Displacement Bladder Pump; DB = Disposable Bailer.
NM = Not Measured

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Surface water samples were collected by dipping clean sampling containers directly into the surface water to be sampled. The samples were collected from 5 cm below the water surface. The VOC samples were collected first and with as little agitation as possible to prevent potential volatile chemicals from escaping. The VOC samples were collected first because the surface water to be sampled was undisturbed in its natural conditions. Other samples were then collected in the appropriate containers. Sampling proceeded from downstream to upstream locations.

Sediment samples were collected below the point where surface water samples were obtained. The sediment sampling, as with the surface water sampling, proceeded from downstream to upstream locations. The water in the drainage ditches at Sites 1, 2B, and 7 was generally shallow thus permitting sample collection to proceed with a trowel. Sediment sample 1-SD4 required the use of a hand auger as access to the sampling media was restricted by the water depth. At Site 25, deeper waters forced CH2M HILL personnel to collect the sediment samples with extended hand augers. It was not deemed necessary to use a Ponar dredge as previously discussed in the RFI work plan. The VOC samples were collected immediately upon retrieving the trowel or hand auger. Remaining sample material was homogenized in a decontaminated stainless steel mixing bowl. Sample jars were then filled with the homogenized sediment.

Soil Sampling

Soil samples were collected at 13 of the 17 sites investigated as part of this RFI. At Sites 1, 2B, and 2C soil borings were advanced to the water table using a drill rig, with samples being collected every 2 feet using split-spoon samplers. Several of the soil samples at Site 2B were collected with an extended hand auger due to the proximity of the water table to the ground surface. At these three sites, samples were screened for contamination in the field and only the two most contaminated samples from each sampling location were submitted for analysis.

At Sites 25, 11, 19, 20 and 26, soil samples were collected with decontaminated stainless-steel hand bucket augers. The samples were collected for 0.5 to 1.0 foot and from 2.0 to 3.0 feet at each sampling location. Only one sample from each sampling location was submitted to the laboratory after a field screening with an OVA to determine contamination.

The soil samples at Sites 1, 16, 18, 21, 23, and 24 were collected from pre-determined depths using decontaminated stainless steel hand augers. At Site 1, two soil samples (1-SS1 and 1-SS2) were collected with hand trowels. The sampling depths were from 0.5 to 1.0 foot at all the sites mentioned above, except at Sites 16 and Site 1, where the sampling depths were 1.0 to 2.0 feet and 0.25 to 0.75 feet, respectively. No field screening was performed at these sites. At Site 23, the soil samples were collected after penetrating the asphalt with a pneumatic hammer.

The same soil sampling procedure was followed at all sites. Once the appropriate depth had been attained, the soil sample was collected and the VOC sample containers were filled first with as little disturbance as possible, using stainless steel implements. The remaining sampling material was homogenized in a mixing bowl with a hand trowel, and then packed into the appropriate sample containers provided by the CH2M HILL analytical laboratory. At locations where field screening was required, the VOC samples at all depths were packaged while the remaining depths were sampled. After sampling to the appropriate depth, the sample that had been determined to be the most contaminated was homogenized and jarred. Volatile samples were not required.

Quality Assurance Sampling

Quality Assurance was an integral part of the RFI's sampling phase. Duplicate samples, field blanks, and trip blanks were collected in the field and submitted to the analytical laboratory to assess the quality of data from the media sampled. The analytical laboratory utilized the duplicate samples to provide a measure of internal consistency of the sample, and estimates of variance and bias.

Duplicate (replicate) samples were collected concurrently with the actual samples in exactly equal volumes, at the same location, with the same sampling equipment. Duplicates were collected at a rate of one duplicate for every 10 or fewer samples per medium. The samples were placed in identical containers. The duplicate samples were preserved and handled in the same manner as the regular samples. Each replicate was evenly split into two samples—one with the sample location number, the second with a different number. This second sample was not labelled as a duplicate; however, the chain-of-custody form had "Do QC" marked next to the second (duplicate) sample number.

The Navy QA/QC contractor received a letter from CH2M HILL field personnel designating the field duplicates after they had been sent to the laboratory. This approach satisfies the Navy QC requirement that laboratory personnel know which samples to run MS/MSDs on, and the EPA practice of collecting blind field duplicates.

Field blanks were collected and analyzed to provide a measure of cross-contamination sources, while equipment blanks provide a measure of decontamination efficiency. Trip blanks accompanied the shipment of volatile organic compound samples every day that volatiles were shipped. Trip blanks indicate whether there is any contamination during shipment and storage. Table D-2 lists the analytical results for trip blanks collected during the RFI.

Table D-2
QUALITY CONTROL SAMPLING DURING THE RFI
TRIP BLANKS

Sample Number	Date	Analysis	Methylene Chloride	Acetone	Trichloro-fluro-methane	2-Butanone	Toluene
TBGP-1	11-19-92	8240	7 b	*	*	*	*
TBGP-2	11-20-92	8010	3.4 c	NA	*	*	*
TB-1229	12-29-92	App IX VOCs	2 bj	*	*	*	*
TB-1230	12-30-92	8240	5 b	10 b	*	*	*
TB-118	01-18-93	8240	2 bj	10 b	2 j	*	*
TB-119	01-19-93	8010	18	NA	*	*	*
TB-120	01-20-93	8010	*	NA	*	*	*
TB-121	01-21-93	8010	*	NA	*	*	*
TB-122	01-22-93	8010	*	NA	*	*	*
TB-125	01-25-93	8240	3 bj	4 j	*	*	*
TB-126	01-26-93	App IX VOCs	5 b	7 j	*	*	*
TB-127	01-27-93	8240	3 bj	7 bj	2 j	*	*
TB-128	01-28-93	App IX VOCs	4 bj	*	*	*	*
TB-129	01-29-93	8240	2 bj	8 j	*	*	*
TB-21	02-01-93	8240	8 b	*	*	*	*
TB-23	02-03-93	8240	4 bj	7 j	*	*	*
TB-24	02-04-93	8240	3 j	*	*	*	*
TB-25	02-05-93	8240	6 b	11 b	*	*	*
TB-223[a]	02-23-93	8240	1 j	*	*	5[j]	1[j]

Detection limits for 8010 and 8020 volatiles were 1 ppb.
Detection limits for 8240 and Appendix IX volatiles were 5 or 10 ppb.
NA—Not Analyzed.
*Analyzed for but not detected.
b - Compound detected in associated laboratory blank.
j - Reported value less than quantitation limit.
c - Compound confirmed by GC/MS analysis.
[a]The sample data were qualified as estimated during the data validation process because small bubbles were found in all vials.

Sample Handling

Sample preservation and handling are critical because in the time between sample collection and laboratory analysis, the concentration and distribution of constituents in the sample could be altered by contamination, reaction, degradation, volatilization, sorption, and other processes. The sample handling and analytical methods conformed to EPA document SW-846, *Test Methods for Evaluating Solid Wastes* (EPA, 1986b). Important factors in sample handling and preservation include: use of certain container types for specific analyses, proper temperature control, pH control, chemical additions to minimize changes in the concentration or distribution of constituents, and maximum acceptable sample holding times between collection and analysis.

The analytical laboratory cleaned the sample containers using standard procedures and protocol for RCRA investigations and added sample preservatives to the containers before shipping the containers to the site. The sample containers used to collect samples were compatible with the analyses of interest. Field personnel referred to a guidance document, which was provided by the analytical laboratory, that specified container type with regards to analysis. For instance, water samples to be tested for organics analysis were collected in glass bottles with Teflon-lined caps; whereas, water samples for metals analysis were collected in polyethylene (plastic) bottles. Soil samples were collected in wide-mouth glass bottles with Teflon-lined caps.

All samples were shipped on the day they were collected by Federal Express priority overnight service to the CH2M HILL Analytical Laboratory in Montgomery, Alabama. To prepare the samples for shipment, CH2M HILL personnel placed the samples in metal or plastic Igloo coolers, and packed the coolers with vermiculite in order to avoid bottle breakage. Ice was placed in ziplocked bags and packed in the coolers to keep the samples cooled to 4°C during shipment. The samples were placed on ice as they were collected throughout the day. A chain-of-custody form and return label were sealed in a ziplocked bag and taped to the cooler's inside lid. CH2M HILL field personnel secured the sample cooler with strapping tape and custody seals. All samples reached the laboratory well within their respective holding times.

Decontamination Procedures

CH2M HILL field personnel followed specified decontamination procedures to prevent cross-contamination between samples and sampling locations. The decontamination of drilling equipment was performed with a high-pressure steam cleaner.

All sampling equipment, i.e., hand augers, trowels, mixing bowls, and split spoons were cleaned using the following method:

1. Washed and scrubbed with non-phosphate detergent

2. Rinsed with 10 percent methanol solution

3. Rinsed with a 10 percent hexane solution

4. Rinsed with tap water

5. Rinsed with deionized water

6. Allowed to air dry

7. Wrapped in aluminum foil, shiny side out, to prevent contamination during storage and transport

To clean the interior of the pump used for purging and sampling, 1 gallon of each of the five detergents or rinses listed above were pumped through the pump and Teflon hose.

The water level indicator was decontaminated between monitoring wells using 10 percent methanol and 10 percent hexane solutions.

WDCR706/012.51

Appendix E
In Situ Hydraulic Conductivity Data Analysis

In Situ Hydraulic Conductivity Data Analysis

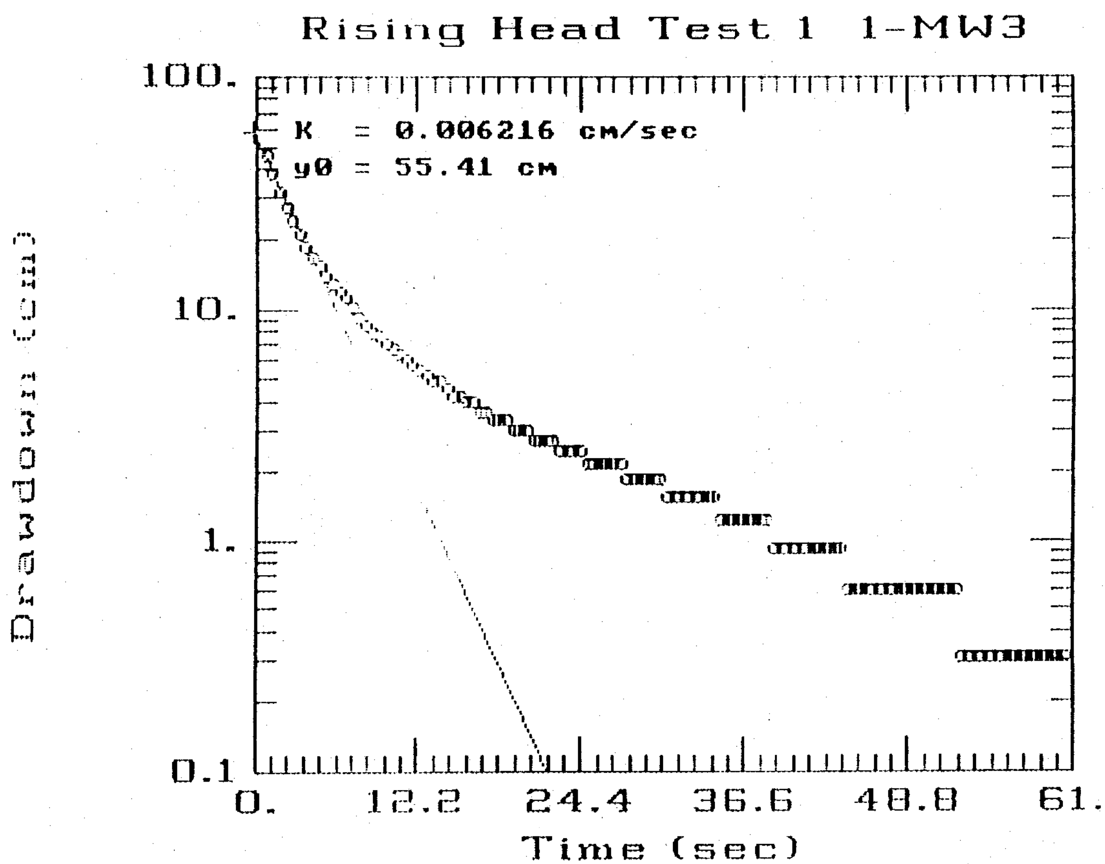
On February 24, 1993, CH2M HILL personnel performed *in situ* hydraulic conductivity tests on six monitoring wells at Site 1. The monitoring wells tested were 1-MW3, 1-MW6, 1-MW7D, 1-MW8, 1-MW8D, and 1-MW9D. The conductivity tests, known as slug tests, record water level fluctuations caused by adding and removing slugs of water from the well. The rise and fall of the water level was recorded by a high-speed Campbell 26X datalogger equipped with two 5-pound per square inch pressure transducers. The datalogger collected data while the water level recovered to its original static elevation. To ensure a representative test had been achieved, a minimum of two rising head tests were performed at each well. Two falling head tests were conducted at 1-MW3. The water level data were applied to Aqtesoli (Geraghty and Miller, 1989), a computer program capable of analyzing slug-test data. All tests were analyzed using the Bouwer and Rice Method (1976) for unconfined aquifers. Using the Bouwer and Rice method of analysis, CH2M HILL hydrogeologists calculated an approximate value of the hydraulic conductivity in the immediate vicinity of the well screen. Table E-1 summarizes the hydraulic conductivities determined from the slug tests at each well. The graphical results of the *in situ* hydraulic conductivity tests performed at Site 1 are included in this appendix.

WDCR702/003.51

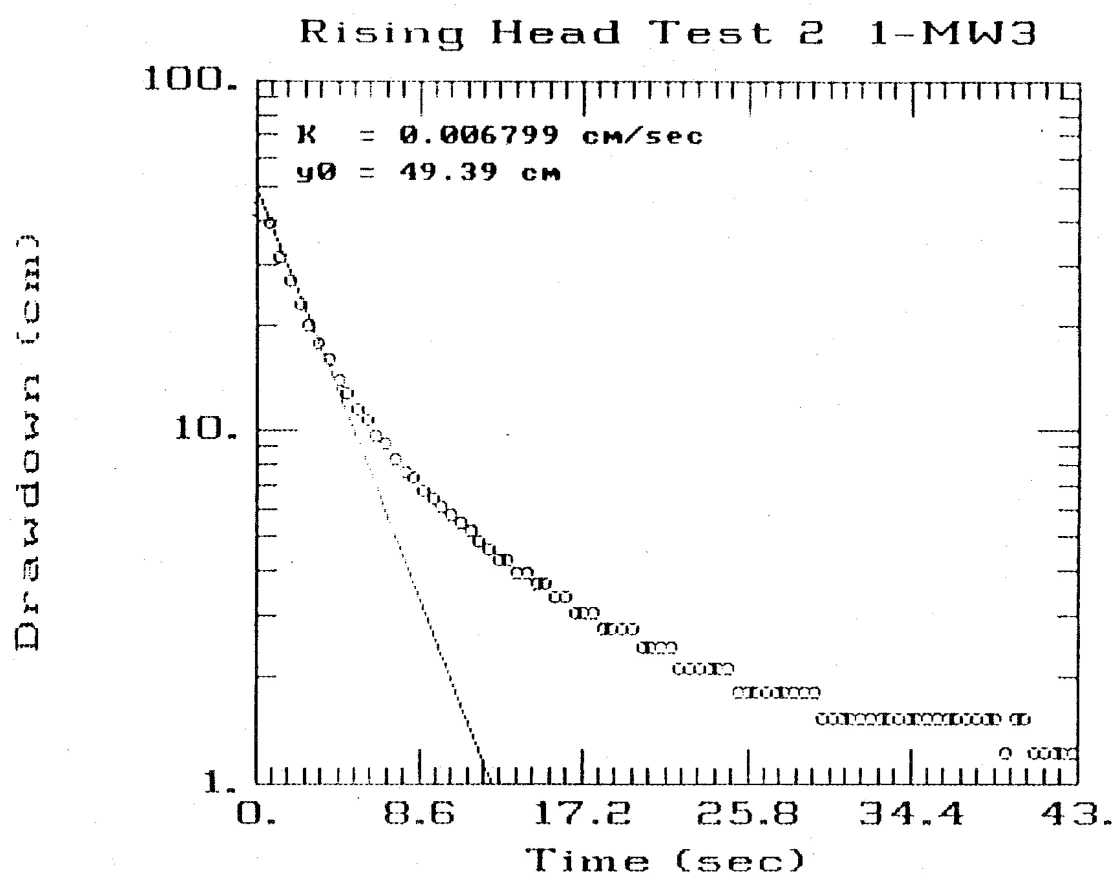
Table E-1
RESULTS OF HYDRAULIC CONDUCTIVITY TESTS
ON SELECT MONITORING WELLS AT SITE 1,
WEST WOODS OIL DISPOSAL PIT
February 1993
(All Figures in cm/sec.)

Monitoring Well	Test Results (cm/sec)	Average Hydraulic Conductivity (cm/sec)
1-MW3	6×10^{-3} 6×10^{-3} 3×10^{-3} 3×10^{-3}	5×10^{-3}
1-MW6	2×10^{-3} 1×10^{-3}	2×10^{-3}
1-MW7D	6×10^{-5} 7×10^{-5}	7×10^{-5}
1-MW8	4×10^{-3} 6×10^{-3} 6×10^{-3}	5×10^{-3}
1-MW8D	9×10^{-5} 1×10^{-4}	1×10^{-4}
1-MW9D	5×10^{-5} 4×10^{-5}	5×10^{-5}

WDCR702/003.51

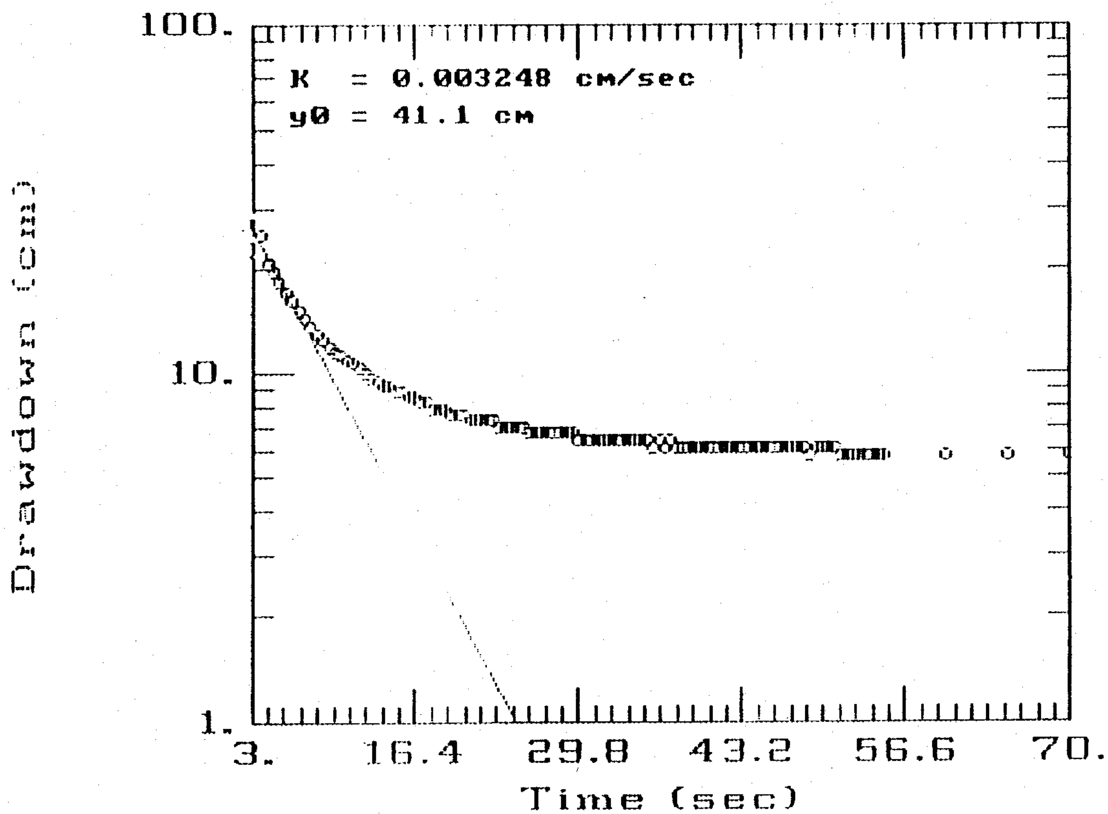


OC-00175-03.13-12/01/93



OC-00175-03.13-12/01/93

Falling Head Test 1 1-MW3



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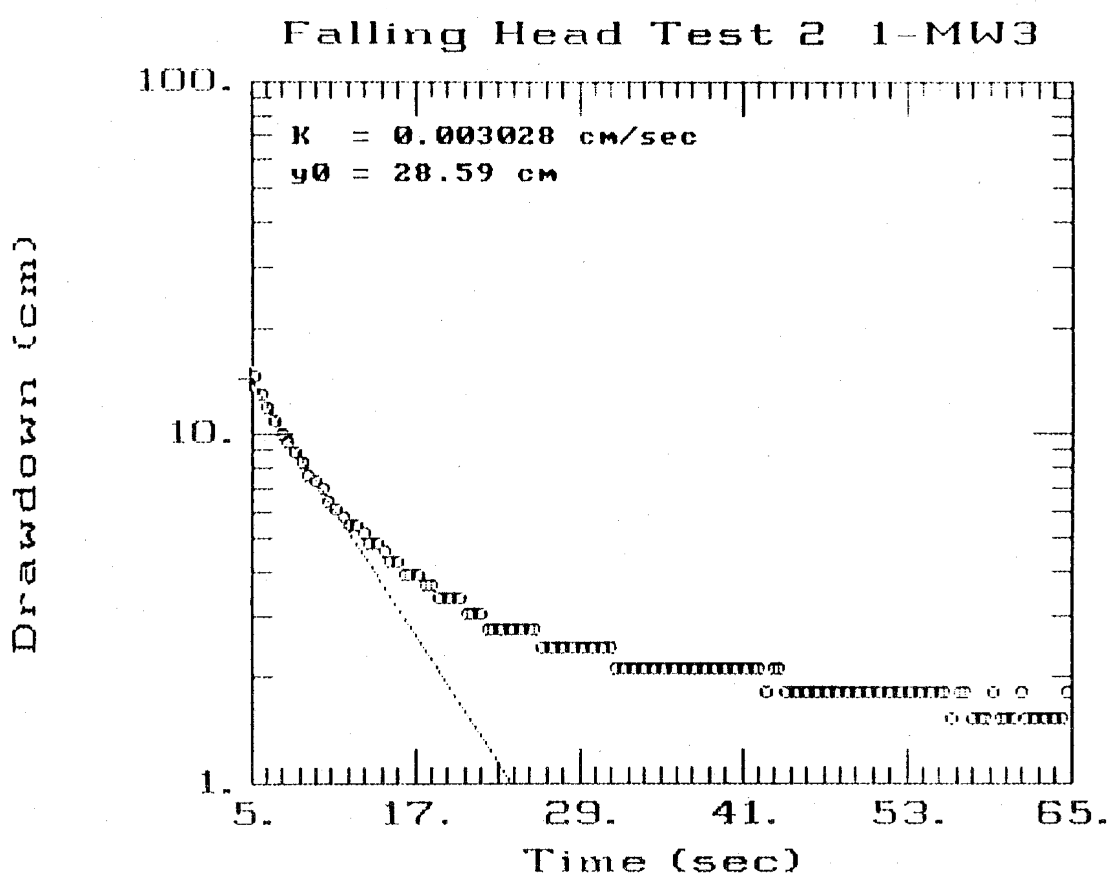

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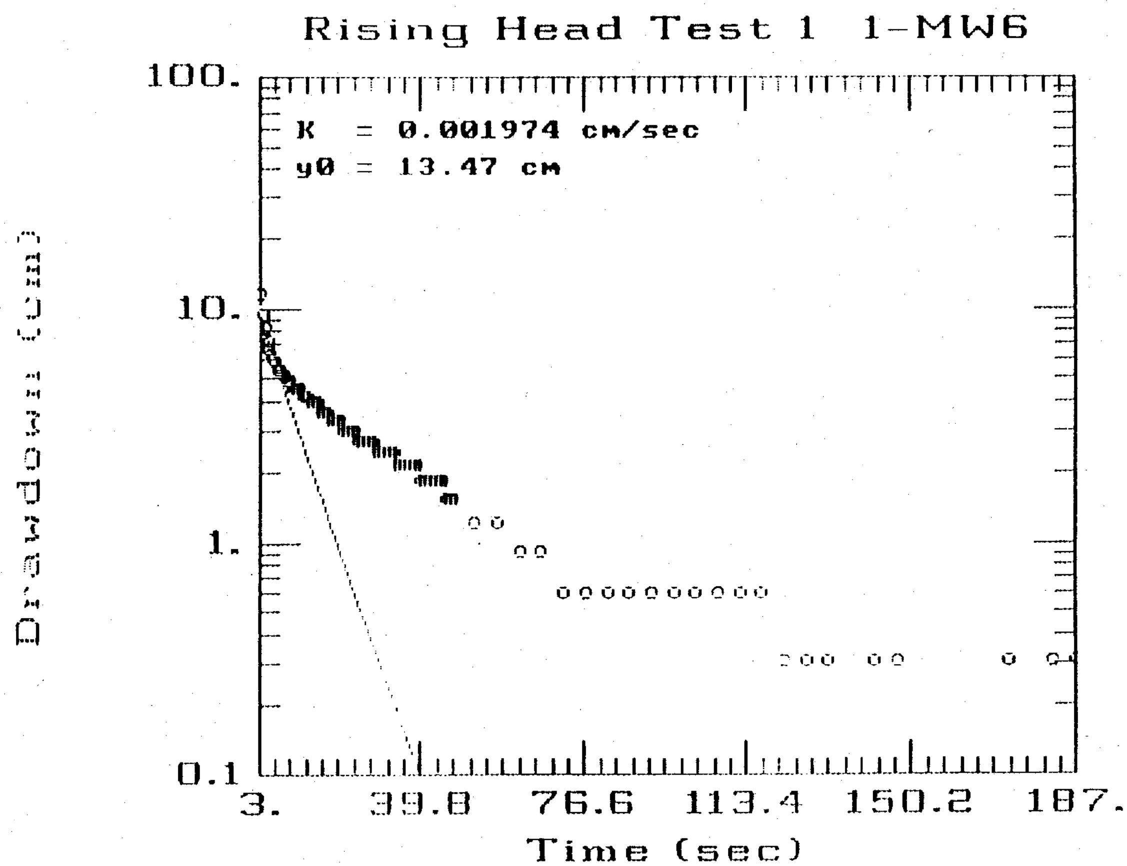

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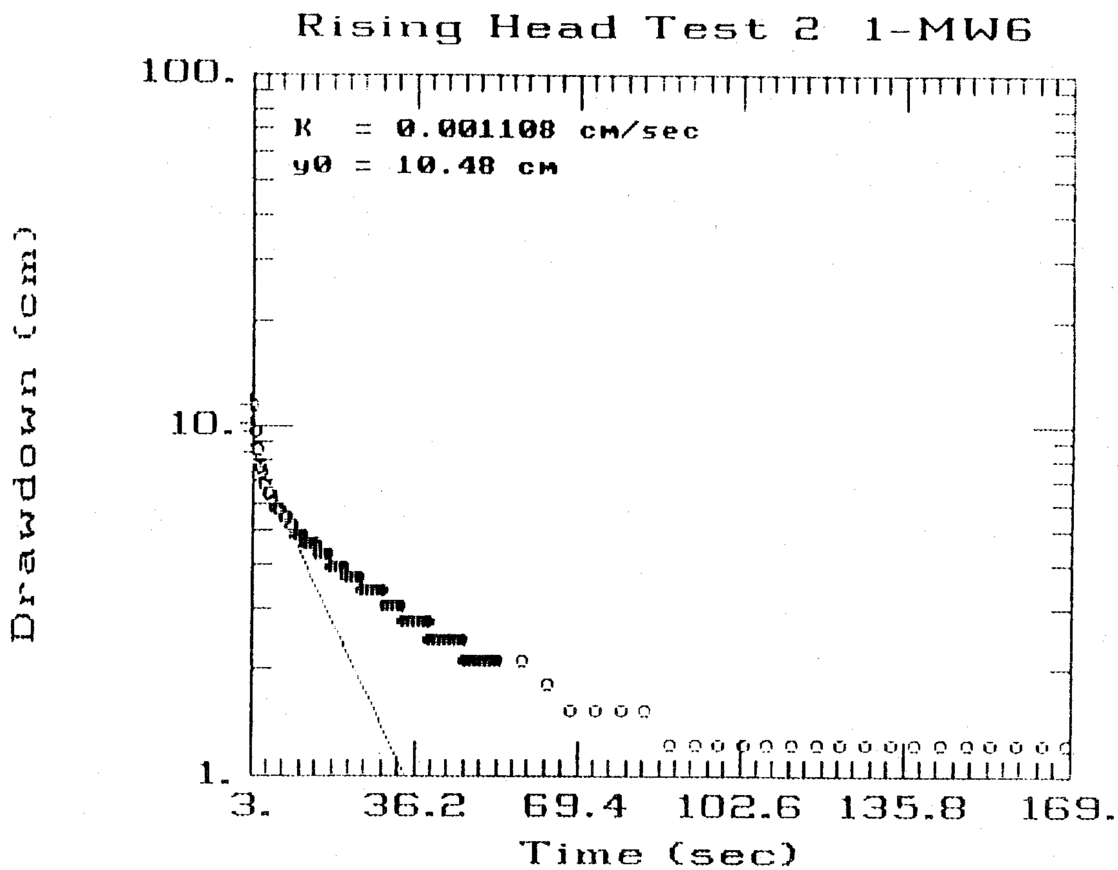

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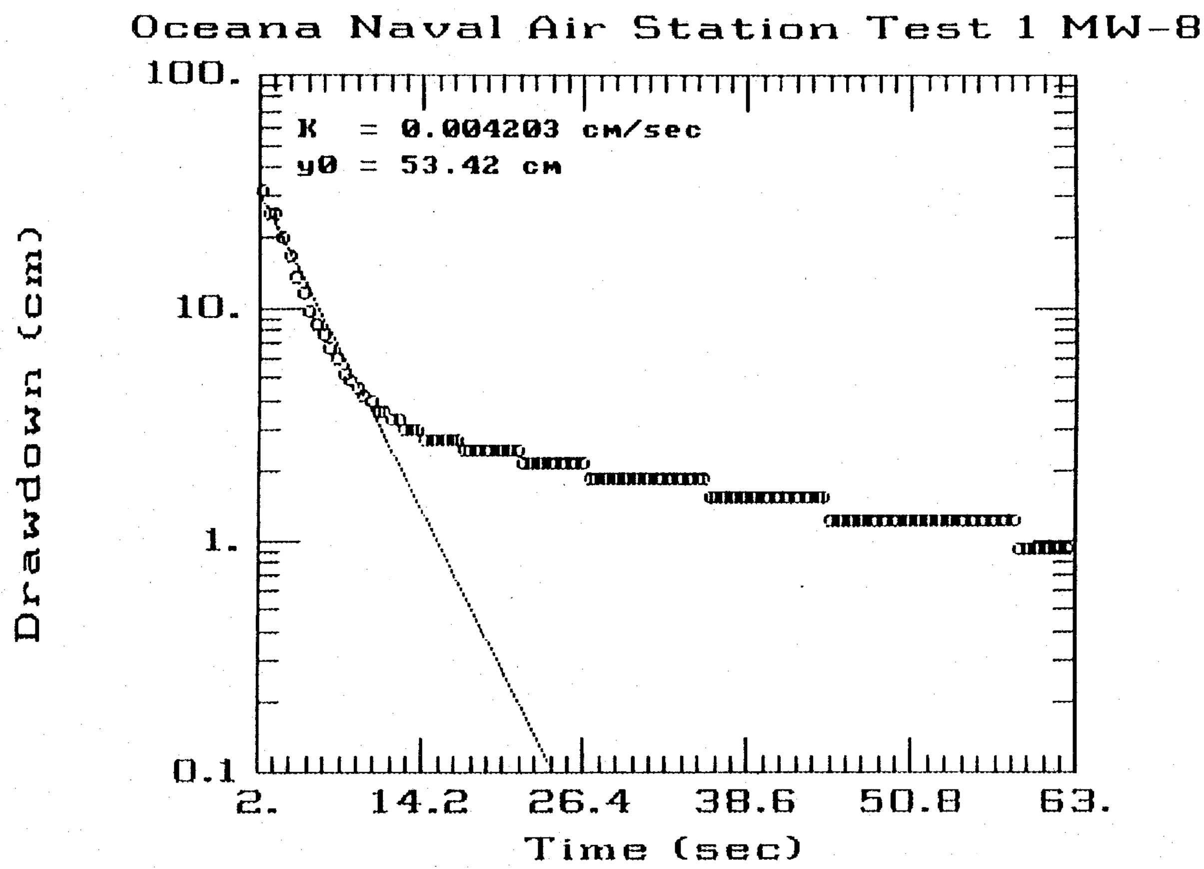

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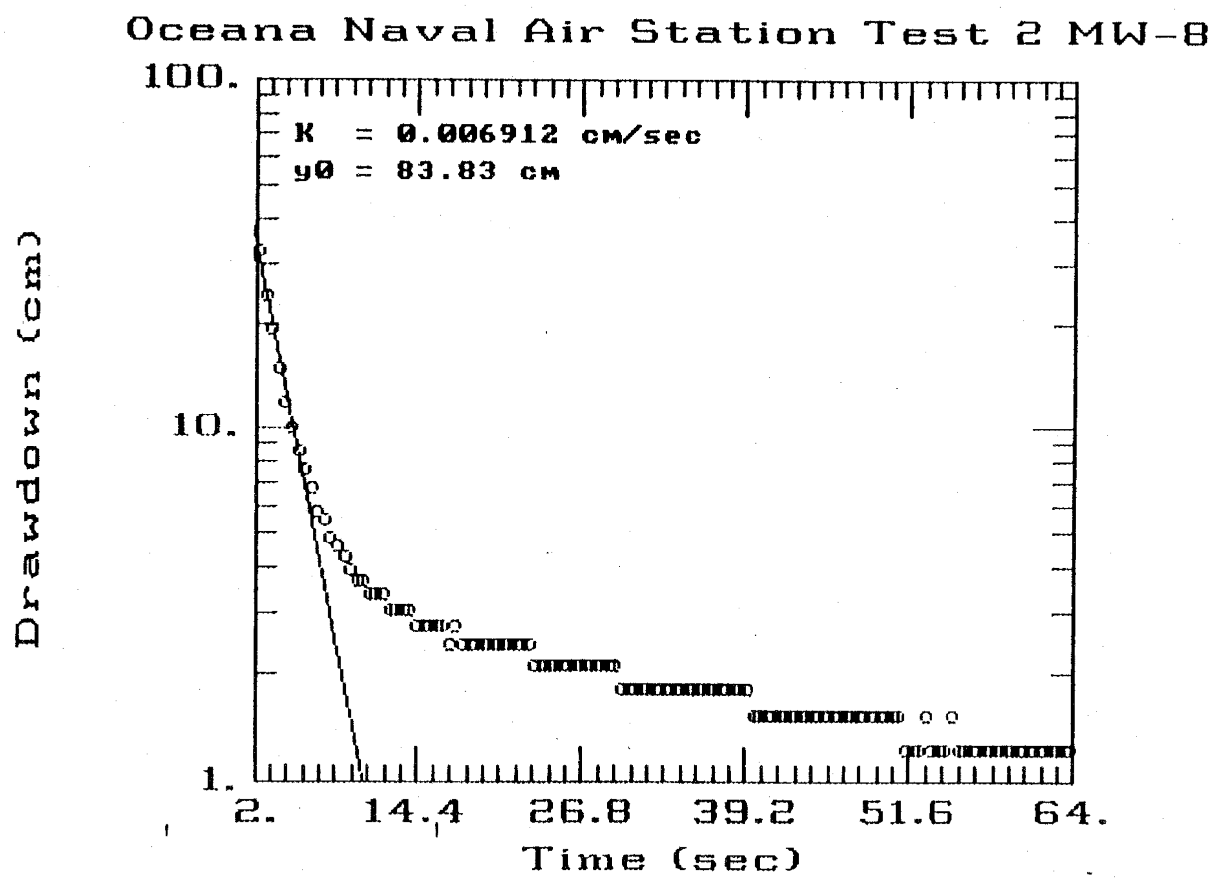

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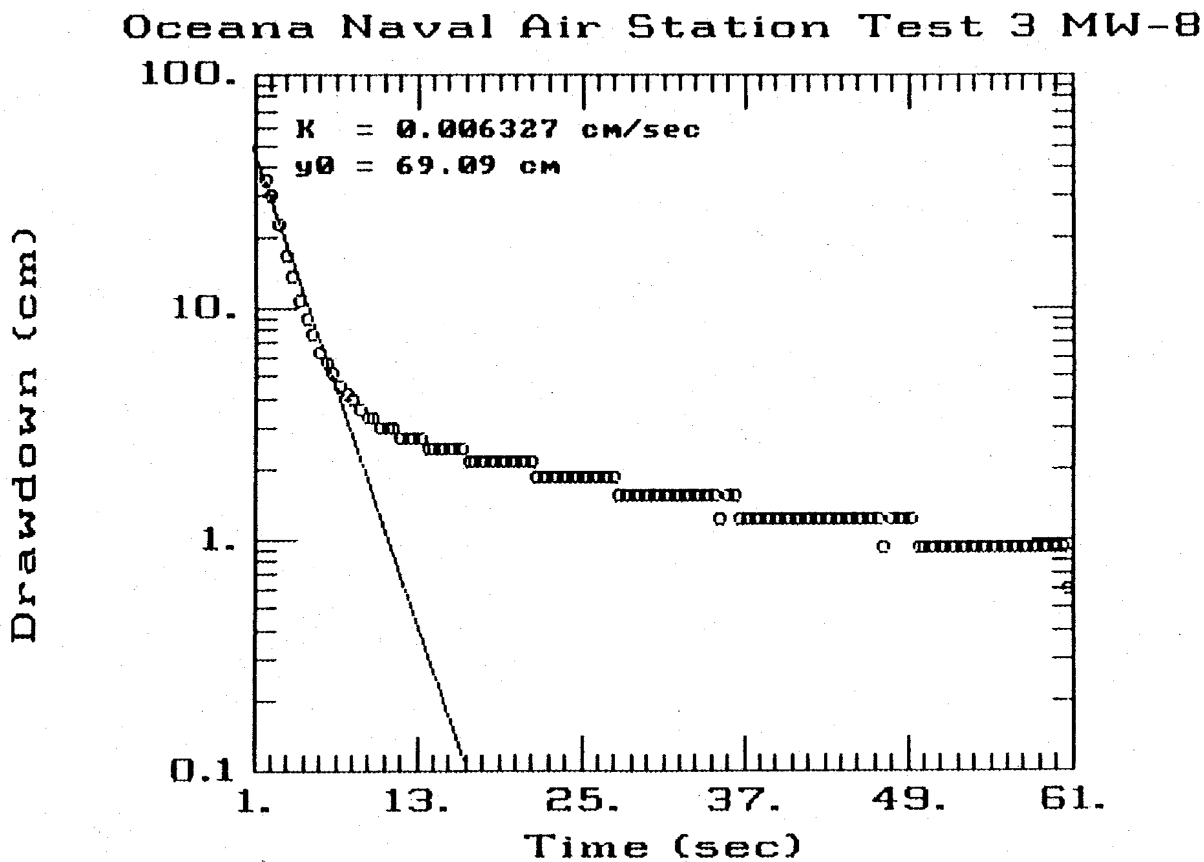

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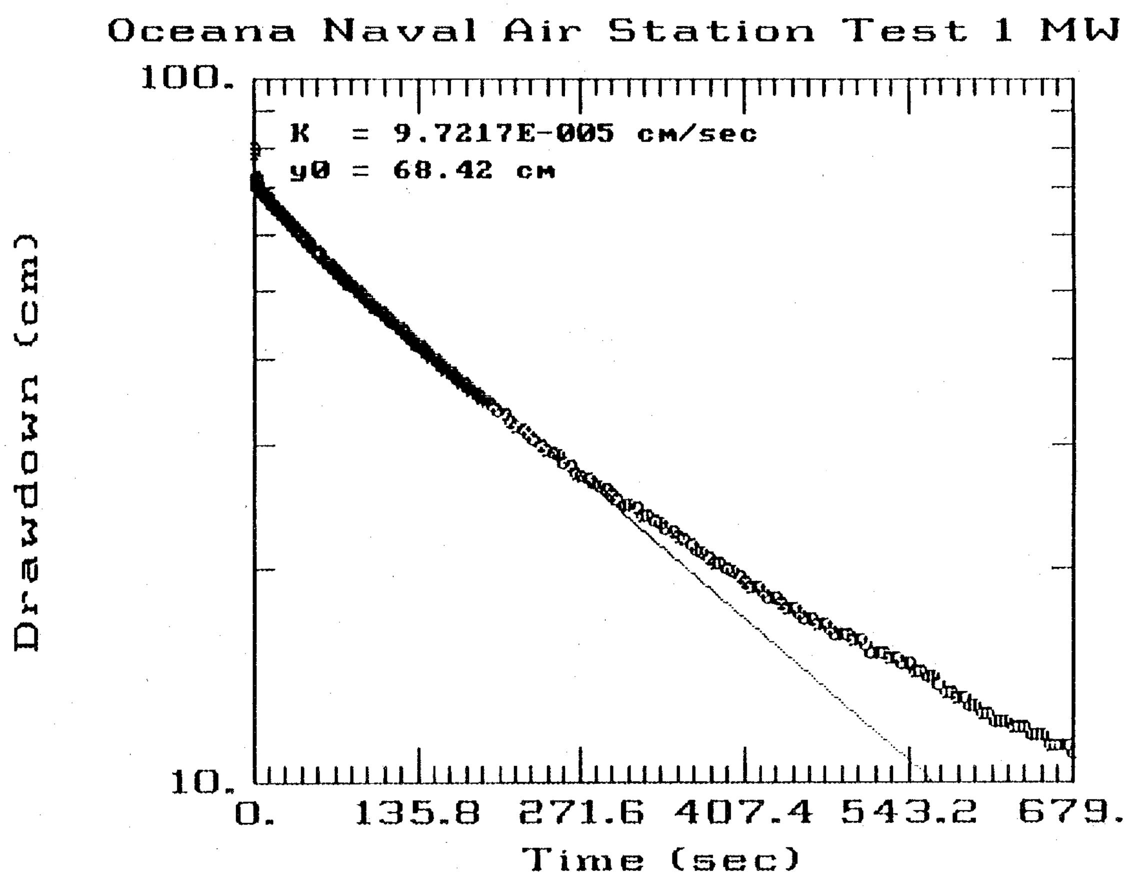
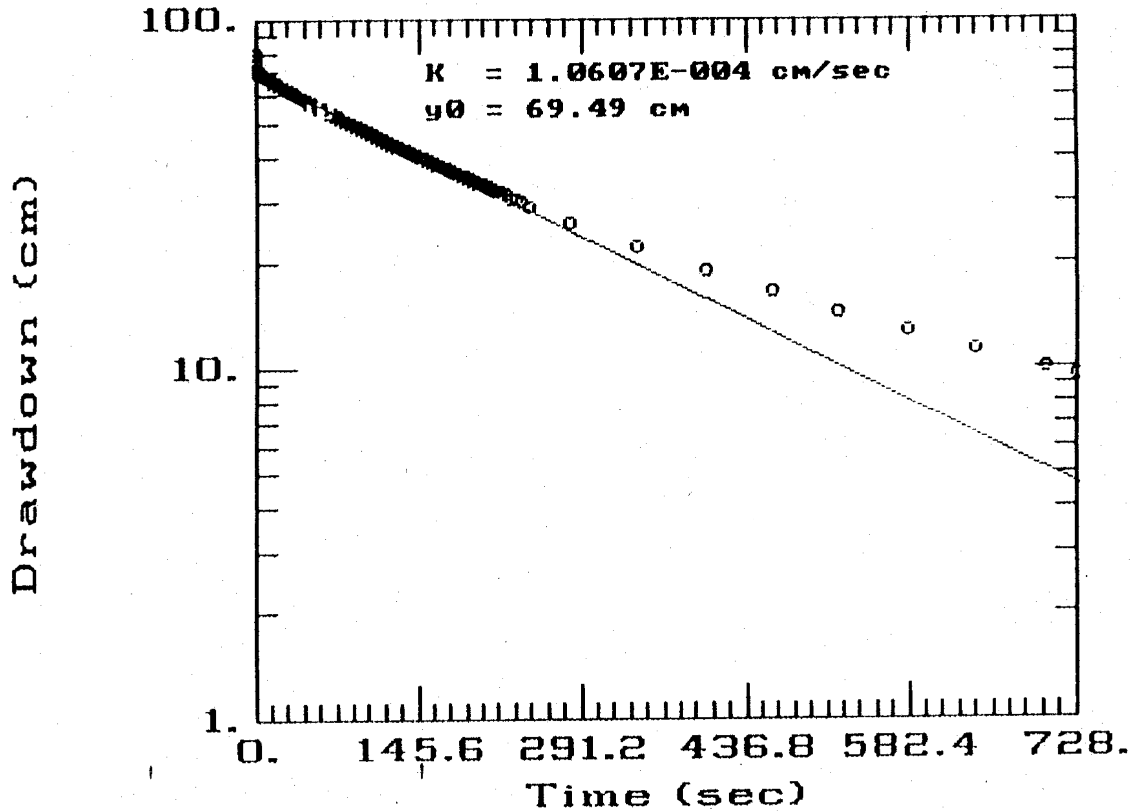


OC-00175-03.13-12/01/93

Oceana Naval Air Station Test 2 MW-8D



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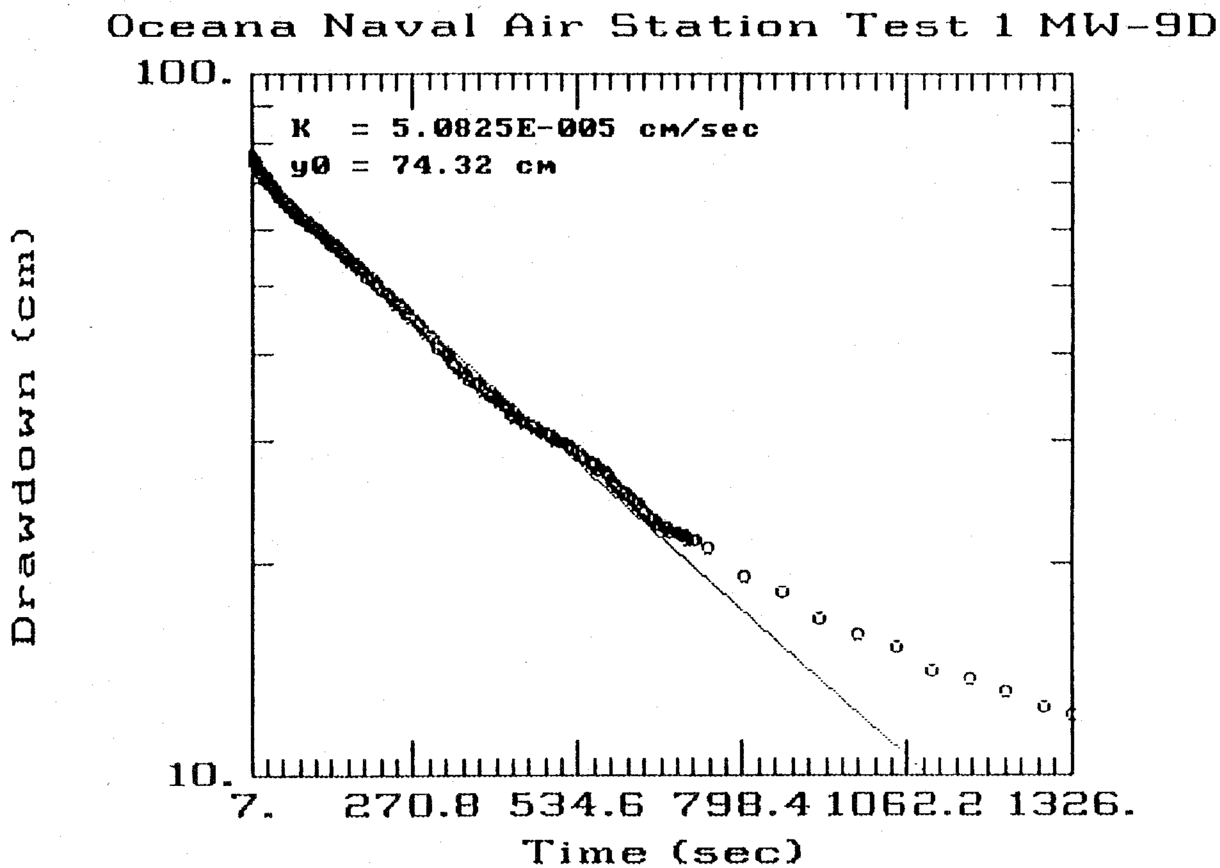
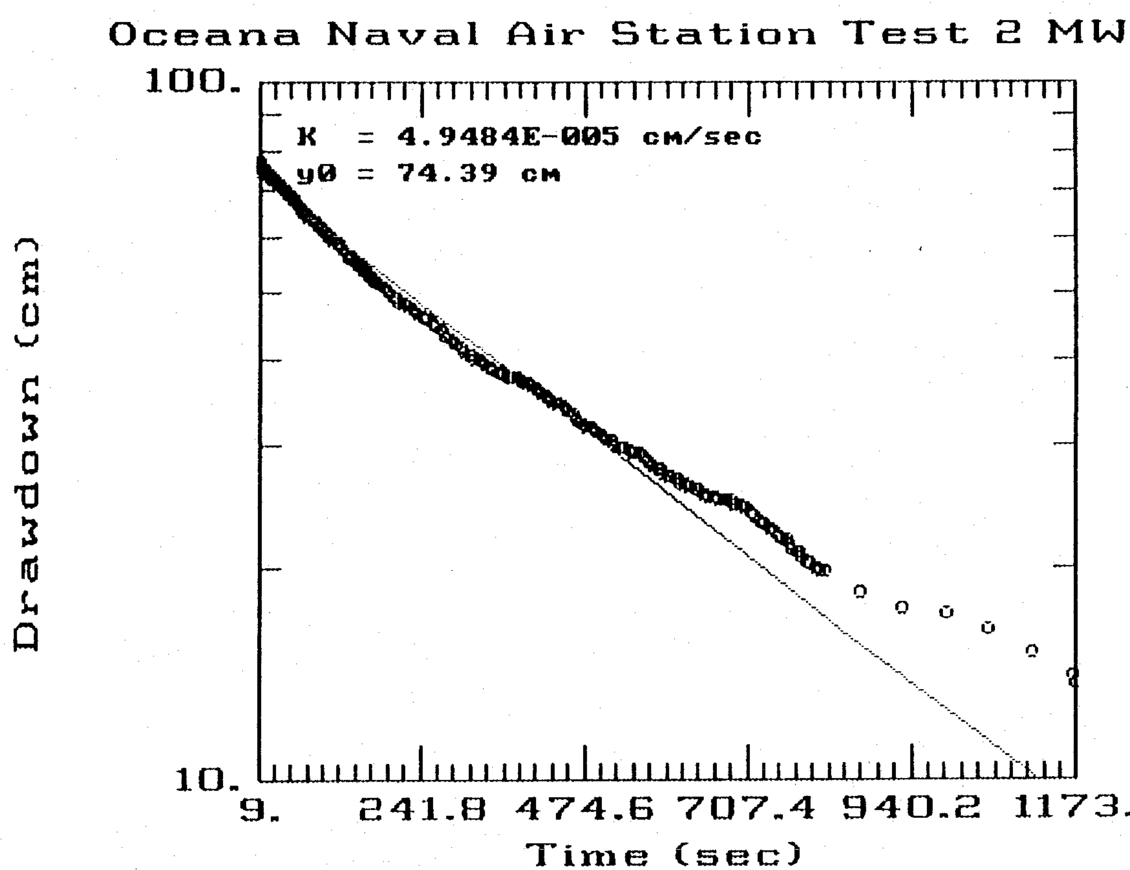
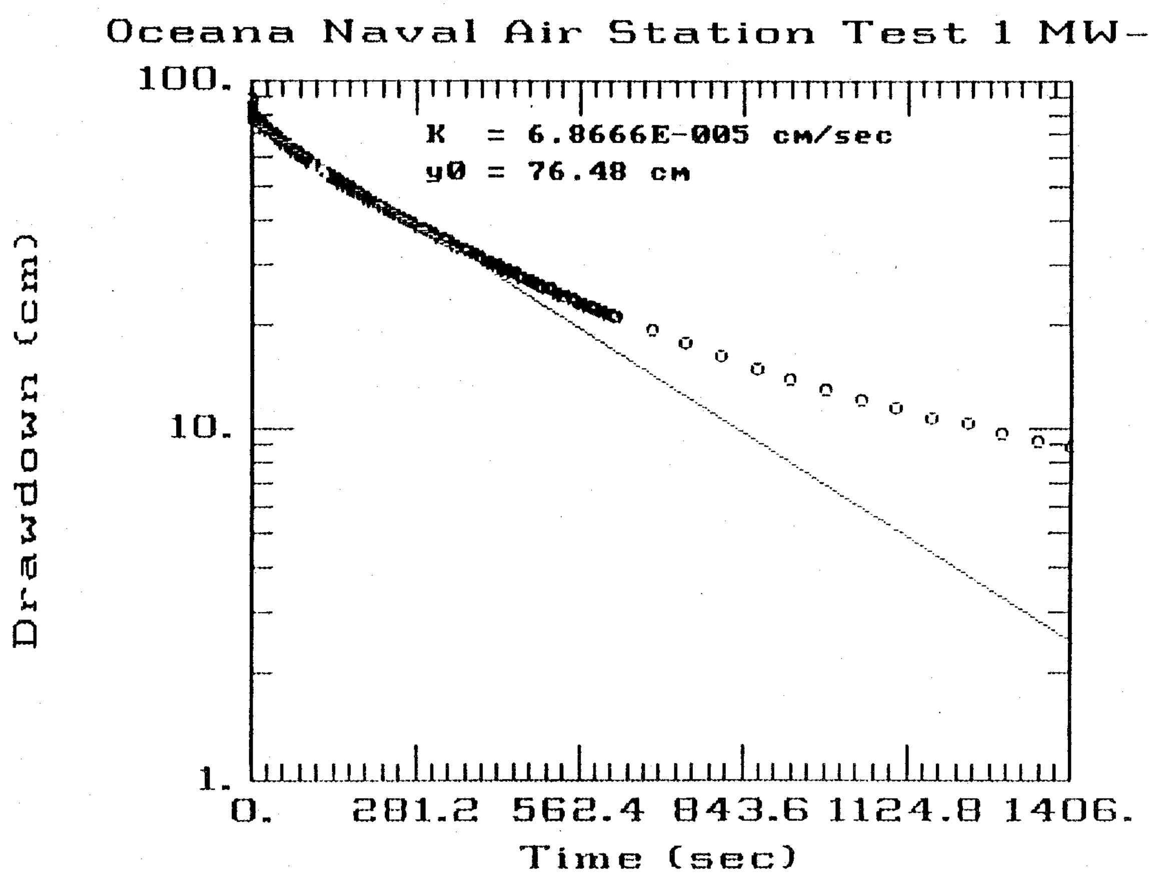


OC-00175-03.13-12/01/93

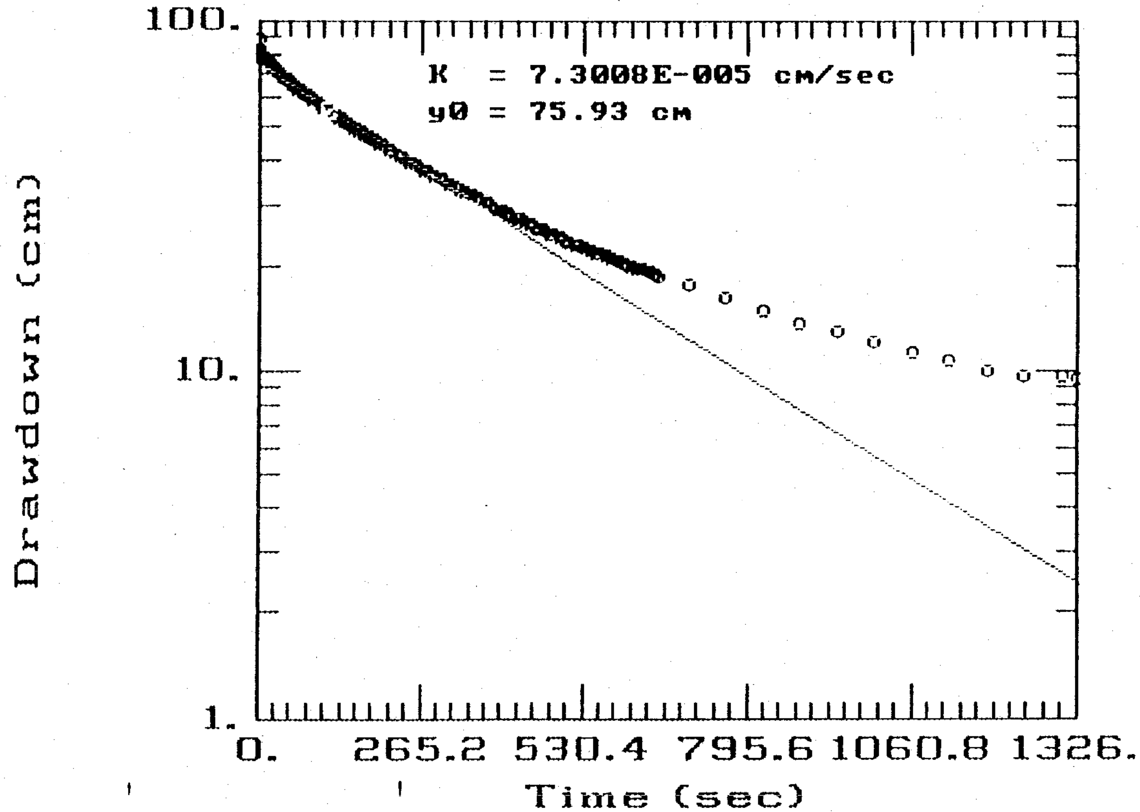


OC-00175-03.13-12/01/93



OC-00175-03.13-12/01/93

Oceana Naval Air Station Test 2 MW-7D



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Appendix F
Other Field Activities

Appendix F
Other Field Activities

To complete the field operations which were undertaken as part of this RFI, other field activities such as surveying, drum handling and groundwater collection proved necessary.

The surveying was performed by Baldwin and Gregg of Norfolk, Virginia, on the 2nd and 5th of February, 1993. The elevations of the 25 newly installed monitoring wells were surveyed to an accuracy of ± 0.01 feet. At Site 1, two pre-existing monitoring wells and the soil boring locations were surveyed for horizontal positions. The elevation of benchmarks in the perennially flowing drainage ditches at Site 1 and Site 2B were also surveyed. The surveyed elevations of the monitoring wells are critical to the calculations of groundwater flow gradients. The elevation data are listed in Tables F-1 and F-2.

During the installation of the 25 monitoring wells, drill cuttings were placed in 55-gallon steel drums. These cuttings may be hazardous wastes pending the results of the laboratory analysis; therefore, the drums were sealed and labelled to discourage tampering and to decrease the risks to human health and the environment. Hardin-Huber, Incorporated of Baltimore, Maryland, collected, filled, and sealed the drums under the supervision of CH2M HILL personnel. CH2M HILL personnel labelled the drums in the event that the contents of the drums are included in the remedial process. Solids from drilling decontamination were contained, along with personal protective equipment.

Water from development, purging, and sampling of select wells was also contained. Groundwater that was extracted during the development of the new monitoring wells at Site 2C, and three new monitoring wells at Site 2B (2B-MW1D, MW5D, and MW16) was contained. To assist in the containment of this development water, C & M Waste Oil Distributors of Chesapeake, Virginia, provided a clean tanker truck into which development water was discharged directly. C & M Waste Oil submitted samples of this water for TCLP analysis. After laboratory results came back below TCLP standards, the water was treated and discharged off the station.

WDCR702/007.51

Table F-1
NAS OCEANA MONITORING WELL ELEVATIONS AND DEPTHS

Page 1 of 2

Well	Ground Elevation (Ft. above MSL)	Survey Point Elevation (Ft. above MSL)	Total Depth of Well[c] (Feet)
1-MW1	15.3	17.13	22
1-MW2	17.0	18.59	19
1-MW3	17.3	19.33	19
1-MW4	16.9	19.90	18.5
1-MW5	16.7	19.08	18.5
1-MW6	15.4	18.18	20.5
1-MW7	17.2	19.23	22.5
1-MW7D	17.3	17.68	57
1-MW8	15.2	18.17	22
1-MW8D	15.4	18.46	55
1-MW9D	15.3	17.75	65
2B-MW1	21.8	21.59[a]	19
2B-MW1D	21.73	21.73	55
2B-MW2	18.9	20.34	25
2B-MW3	18.0	19.23	20
2B-MW4	20.9	20.93	19
2B-MW5	21.5	21.49	18
2B-MW5D	21.8	21.80	51
2B-MW6	21.0	21.01	15
2B-MW7	18.7	20.95	14
2B-MW8	18.0	20.02	22.5
2B-MW9	20.5	22.27	20
2B-MW10	22.1	22.07	18
2B-MW11	22.1	22.07	18.1
2B-MW12	18.4	21.29	22.5
2B-MW13	17.9	20.40	21
2B-MW14	17.4	20.41	20
2B-MW15	19.0	21.97	22.5
2B-MW16	21.16	21.16	20

Table F-1
NAS OCEANA MONITORING WELL ELEVATIONS AND DEPTHS

Page 2 of 2

Well	Ground Elevation (Ft. above MSL)	Survey Point Elevation (Ft. above MSL)	Total Depth of Well[c] (Feet)
2C-MW1	20.5	20.14[b]	20
2C-MW1D	20.43	20.43	62
2C-MW2	20.5	20.23[b]	20
2C-MW3	20.1	21.29	18
2C-MW4	18.0	19.56	18
2C-MW5	20.4	20.42	16
2C-MW6	20.7	23.18	22
2C-MW7	20.8	20.81	19.5
2C-MW8	19.0	19.05	18
2C-MW9	17.0	19.33	18
2C-MW9D	17.1	19.45	57
2C-MW10	18.24	18.24	20
2C-MW11	18.47	18.47	24
2C-MW12	17.84	17.84	24
2C-MW13	18.49	18.49	22
2D-MW1	18.9	21.52	17
2D-MW2	22.3	22.26	19
2D-MW3	22.1	22.10	19
2E-MW1	20.3	22.52	19
2E-MW2	19.4	19.43	18.5
2E-MW3	18.9	20.83	18
11-MW1	17.1	19.25	18.5
11-MW2	16.6	19.82	20.5
11-MW3	17.33	17.33	20
22-MW1	16.0	18.61	20
22-MW2	15.6	18.08	28
22-MW3	19.2	21.18	23
22-MW4	16.6	18.77	23

[a]The survey point is the top of a 6″ protective steel casing, which is below grade and covered by a flush mount.
[b]The survey point is the top of PVC, which is below grade.
[c]The total depth of the well is estimated from the well log and drilling field notes.

WDCR692/040.51

Table F-2
COORDINATES OF SOIL BORINGS AND MONITORING WELLS
AT SITE 1, WEST WOODS OIL DISPOSAL PIT

Page 1 of 2

Soil Borings	Coordinates
1-SB-01	N 188716.0 E 2720243.0
1-SB-02	ND
1-SB-03	N 188765.0 E 2720247.0
1-SB-04	N 188782.0 E 2720291.0
1-SB-05	ND
1-SB-06	N 188810.0 E 2720137.0
1-SB-07	N 188725.0 E 2720195.0
1-SB-08	N 188724.0 E 2720311.0
1-SB-09	N 188642.0 E 2720221.0
1-SB-10	N 188816.0 E 2720235.0
1-SB-11	N 188868.0 E 2720247.0
1-SB-12	N 188925.0 E 2720262.0
1-SB-13	N 188850.0 E 2720333.0
1-SB-14	N 188599.0 E 2720270.0
1-SB-15	N 188514.0 E 2720304.0

Table F-2
COORDINATES OF SOIL BORINGS AND MONITORING WELLS
AT SITE 1, WEST WOODS OIL DISPOSAL PIT

Page 2 of 2

Monitoring Wells	Coordinates
1-MW-3	N 188563.0 E 2720557.0
1-MW-4	N 188782.3 E 2720198.9
1-MW-5	N 188682.5 E 2720187.3
1-MW-6	N 188509.0 E 2720247.0
1-MW-7	N 188669.0 E 2720016.0
1-MW-7D	N 188676.0 E 2720017.0
1-MW-8	N 188932.0 E 2720086.0
1-MW-8D	N 188924.0 E 2720090.0
1-MW-9D	N 188708.0 E 2720395.0

Notes:

Reference Bench Mark: Chiseled square on door sill to Building #3002 west of Fire Prevention Training Pit, NAS Oceana. Elevation = 16.11

ND - No Data. Soil boring could not be located by surveyors due to site conditions.

Work performed by Baldwin and Gregg, Ltd., Norfolk, Virginia.

WDCR700/026.51

Appendix G
Data Validation Report

Appendix G
Data Validation Report

Introduction

Soil and water samples were collected as part of the Oceana Naval Air Station (NAS) RCRA Facility Investigation (RFI). The purpose of this technical memorandum (TM) is to summarize the results of the review and validation process. Data validation is the technical review of a data package using criteria established in the Data Quality Objectives of the Quality Assurance Project Plan. The sample results are included in the main body of the RFI report and are not included in this memorandum.

All the samples were submitted to, and analyzed by, the CH2M HILL laboratories located in Montgomery, Alabama, and Gainesville, Florida.

Data Package Deliverables

When samples were submitted to the laboratory, they were assigned unique, eight-digit numerical sample identifiers. The first five digits of the laboratory sample number identify the sample batch, and the last three numbers indicate each unique field sample.

Samples were submitted for analysis using Naval Energy and Environmental Support Activity (NEESA) Level C quality control (QC). Level C data package deliverables are summarized in Table G-1.

Level C Review and Validation Criteria

Samples that were analyzed using SW846 methods were reviewed and validated using the process outlined in *Sampling and Chemical Analysis Quality Assurance Requirements for the Navy Installation Restoration Program, NEESA 20.2-047B (June 1988 revision),* and using laboratory-specific acceptance criteria. As each data package was reviewed, a worksheet was completed for each analysis. These worksheets were developed to act as a checklist for the data reviewer.

Any nonconformances with the data package were noted on the worksheet and then appropriate data validation qualifying flags were assigned to the data. A guidance document was developed to assist reviews in applying validation flags. The results with data validation flags are included in tables in Chapter 4.

Table G-1
LEVEL C DATA PACKAGE DELIVERABLES

ORGANICS (GC/MS)

Form	Purpose
I	Sample results
II	Surrogate spike results
III	MS/MSD spike results
IV	Method blank data
V	GC/MS tuning data
VI	Initial calibration data
VII	Continuing calibration data
VIII	Internal standard area data and retention time summary

ORGANICS (GC)

Form	Purpose
I	Sample results
II	Surrogate spike results
III	MS/MSD spike results
IV	Method blank data
VI	Initial calibration data
VII	Continuing calibration data
VII	Pesticide degradation study (for organochloride pesticides only)
VIII	Analytical sequence
X	Compound ID summary

METALS

Form	Purpose
I	Sample results
II	Initial and continuing calibration data
III	Method blank results
IV	ICP interference check sample results
V	Spike recovery data
VI	Duplicate sample results
VII	Laboratory control sample results
VIII	Standard addition results
X	Instrument detection limit study results
XI	Interelement correction factors (ICP), parts I and II
XII	ICP linear range
XIII	Sample Preparation log
XIV	Analysis run log

Organic Analyses

Volatile organic chemicals (VOCs), semivolatile organic chemicals (SVOCs), polynuclear aromatic hydrocarbons (PAH), pesticides (both organochlorine and organophosphorus), polychorinated biphenyls (PCBs), herbicides, and dioxins/furan were analyzed using SW846 methods, and data were reviewed and validated using the *NEESA 20.2-047B* (June 1988 revision) guidance document. This guidance document lists criteria for evaluating (form-by-form) the data package. The raw experimental data were summarized and presented on the appropriate form (organic Form I thru X) because no raw data were included in the data package. See Table G-1 for list of the forms and Table G-2 for a list of holding time requirements to be met.

Inorganic Analyses

All the inorganic data (metals and cyanide, total recoverable petroleum hydrocarbons, and ignitibility) were generated using SW846 and were reviewed and validated using the guidance document, *NEESA 20.2-047B* (June 1988 revision). This guidance document lists criteria for evaluating (form-by-form) the data package. The raw experimental data were summarized and presented on the appropriate form (inorganic Form I thru XIV) since no raw data were included in the data package. See Table G-1 for a list of forms.

Qualifying Flags

Samples that did not meet the acceptance limit criteria are indicated with a qualifying flag, which indicates a problem with the data. The following flags were used:

U	Undetected.	Analyte was analyzed for but not detected above the method detection limit.
J	Estimated.	The analyte was present, but the reported value may not be accurate or precise.
UJ	Undetected.	Quantitation limit may be inaccurate or imprecise.
R	Rejected.	The data was rejected because the corresponding QC data was not within the method-specified limits.

It is important to note that laboratory qualifying flags are included on the data summary form, Form I, which is submitted to the project by the laboratory. However, during the data review and validation process the laboratory qualifying flags are evaluated and replaced with validation flags.

Table G-2
HOLDING TIMES

Analysis	Matrix	Holding time (days) Extraction	Analysis
VOC	water soil	-- --	14 days 14 days
SVOC	water soil	7 days 7 days	40 days 40 days
Pest/PCBs	water soil	7 days 7 days	40 days 40 days
Phos-pest	water soil	7 days 7 days	40 days 40 days
Herbicides	water soil	7 days 7 days	40 days 40 days
Metals	water soil	-- --	180 days 180 days
Mercury	water soil	-- --	28 days 28 days
Cyanide	water soil	-- --	14 days 14 days

Abbreviations:
- VOC Volatile organic compounds
- SVOC Semivolatile organic compounds
- Pest/PCBs Organochloride pesticides and polychlorinated biphenyls
- Phos-pests Organophosphorus pesticides

Validation Results

The data were reviewed and validated as indicated in the preceding sections. As each data package was reviewed, a worksheet was completed for each analysis. Any non-conformances with the data package were noted on the worksheet and then appropriate flags were assigned to the data. Details of non-conformances were included in the completed worksheets; therefore, only general non-conformances are discussed in this section. Overall, the data quality objectives for precision and accuracy as described in SW846 and the completeness objective of 85% were achieved. The data are acceptable as qualified and can be used in the decision making process with the exceptions noted below.

Samples were collected from November 19, 1992 through February 23, 1993. There were no equipment blanks associated with the samples that were collected on the dates of November 19, November 20, December 29, December 30, 1993, and February 23, 1993. There were trip and equipment blanks that were analyzed by method 8240 by GC/MS while the associated samples were analyzed by method 8010 or 8020 by GC in another laboratory. During the review process, it was determined that these blanks cannot be used to qualify the data because we cannot compare results produced by two separate laboratories by two separate methods.

The Blank/Spike Control Sample results were within the laboratory acceptance criteria for all parameters.

Organics

VOC Method 8240 and VOC Appendix IX

Acetone and methylene chloride are used as extraction solvents; hence, they are common laboratory contaminants. When detected in a sample, the concentration reported is the actual concentration in the sample i.e. correction for contamination also evidenced in method blank was not made. Therefore all the acetone and methylene chloride detected in these specific samples (described below) can be attributed to laboratory contamination and positive results less than ten times the method blank concentrations were considered and detection limits were qualified "UJ" as estimated.

Four soil samples (20-SS2-3, 20-SS3-1, 23-SS2, and 1-SB15) were analyzed outside the holding time limit (see Table G-2) and the sample data were qualified as estimated.

Small bubbles were found in all vials for trip blank TB-223 and results were qualified as estimated.

Surrogate recovery for sample 20-SS4-1 was low and results were qualified as estimated.

Three large peaks were found in the chromatograms of two aqueous samples (2E-MW3 and 2E-MW2) and equipment blank EQB2E-1. No action was taken because library searches were not requested and also, the method blank chromatogram was provided to show that these were not laboratory artifacts.

All field duplicate results were in good correlation except for the duplicate pair of soil samples 26-SB2-3 and 26-SB30-3, and for 22-SD1 and 22-SD11. No qualification was performed.

VOC Method 8010

The volatile vials of sample 2CGP-13 had headspace and therefore, sample positive results were qualified ''J'' as estimated and non-detects were rejected ''R'' as unusable.

Compounds dichlorodifluoromethane and 1,1-dichloroethene were not confirmed on the second column analyses for sample 2CGP-13. Therefore, results were qualified ''U'' as undetected.

All positive results for samples 2BGP-15 and 2BGP-17 were qualified ''N'' as tentatively identified because results were not confirmed by second column analyses. QC level 1N was requested which does not require second column confirmation. This was quickly corrected and all the remaining analyses were performed with NEESA level C QC (2N). Samples 2BGP-13, 2BGP-17 and 2CGP-11 had headspace in them and therefore the nondetect results are being rejected and detects qualified ''J''.

In this case, the relative response factors and % RSDs could not be verified. According to SW846 methodology, the initial calibration curves can also be used. The coefficient of determination (R^2) were verified and results were found to be acceptable (greater than 0.990).

VOC Method 8020

All positive results for sample 15GP-6 were qualified ''N'' as tentatively identified because results were not confirmed by second column analyses. QC level 1N was requested which does not require second column confirmation. This was quickly corrected and all the remaining analyses were performed with NEESA level C QC (2N).

For initial calibration curves, all R^2 results were acceptable.

SVOC Method 8270 and SVOC Appendix IX

Di-n-butylphthalate and bis(2-ethylhexyl)phthalate are common laboratory contaminants. Results of these compounds found in the samples, if less than ten times the blank concentrations, were qualified ''UJ'' as estimated.

Two base-neutral surrogate recoveries for field blank FB22-1 were low and therefore, the base-neutral fraction were qualified as estimated.

All field duplicate results were in good correlation except for the duplicate pair of samples 2E-MW1 and 2E-MW30. No qualification was performed.

PAH Method 8100

Sample 1-MW4LN exceeded the 7-day extraction holding time and results were qualified as estimated.

All field duplicate results were in good correlation except for the duplicate pair of soil samples 1-SB13 and 1-SB21, and for 26-SB2-3 and 26-SB30-3. No qualification was performed.

For initial calibration curves, all R^2 results were acceptable.

OC Pest/PCB Method 8080 and OC Pest/PCB Appendix IX

Five samples, 1-SB7, 1-SB8, 1-SB9, 1-SB20, and 1-MW4LN, and equipment blank EQB22-2, exceeded the extraction holding time and results were qualified as estimated.

For initial calibration curves, all R^2 results were acceptable.

Kepone Method 8080

Three samples, 1-SB7, 1-SB9, and 1-SB20, and equipment blank EQB22-2, exceeded the extraction holding time and results were qualified as estimated.

For initial calibration curves, all R^2 results were acceptable.

OP Pest Method 8140

Sample 16-SS1 exceeded the extraction holding time and results were qualified as estimated.

For initial calibration curves, all R^2 results were acceptable.

Herbicide Method 8150

Equipment blank EQB22-2, and samples 16-SS1, 18-SS1, and 18-SS2, exceeded the extraction holding time and results were qualified as estimated.

For initial calibration curves, all R^2 results were acceptable.

Dioxin/Furan

All QC criteria were met.

Inorganics

Metals and Cyanide

The non-detect results of antimony for samples 1-SD2, 1-SD3, 1-SD4, 26-SB3-1, 26-SB2-3, 26-SB30-3, 26-SB4-3, 26-SB5-3, 1-SS1, and 2E-SS9-3, selenium for samples 25-SW1, 25-SW2, EQB23-1, and EQB11-1, and arsenic for EQB11-1, were rejected because of low spike recoveries. Each of the samples was spiked with a known amount of these analytes before the samples were prepared for analysis. The sample results were rejected when the recovery was less than thirty percent as required by the NEESA guidance.

TPH and Ignitibility

The QC criteria were met.

Overall Assessment

All the data were reviewed against the data quality objectives defined earlier in the Quality Assurance Plan. Using NEESA level C deliverables, it is difficult to assess the accuracy, precision, and completeness because the required raw data are not available as they are with higher levels of QC. In some cases, the field duplicate results did not match well. On occasions mentioned earlier, equipment blanks were not taken with some samples. There were also cases when the volatile trip and equipment blanks associated with field samples were analyzed by different methods by a different laboratory, and therefore the presence or absence of common field contaminants cannot be verified. Overall, the data met the expected data quality objectives and can be considered acceptable as qualified and can be used in the decision making process.

WDCM94/027.51

Appendix H
Pre-CMS Analytical Data

TABLE H-1
PRE-CMS SOIL DATA COLLECTED DURING THE NAS, OCEANA RFI
December 1992 to February 1993

Sample Location	SITE 1				Site 2B				Site 2C				Site 2E		
	1-SB9	1-SB10	1-SB12	1-SB14	2B-SB5	2B-SB5	2B-SB1	2B-SB1	2C-SB2	2C-SB2	2C-SB3	2C-SB3	2E-SS6	2E-SS8	2E-SS10
Depth	0-2 ft.	4-6 ft.	4-6 ft.	0-2 ft.	1-3 ft.	3-5 ft.	3-5 ft.	5-7 ft.	1-3 ft.	3-5 ft.	1-3 ft.	3-5 ft.	2-3 ft.	0.5-1 ft.	2-3 ft.
Percent Solids	74.4	83.9	90.9	84.3	81.7	81.8	78.1	79.9	87.4	82.6	83.2	74.3	90.0	74.1	79.4
TOC (mg/kg)	3,900	3,340	13,600	4,120	5,050	3,480	2,740	1,490	3,080	23,400	3,530	4,570	4,710	18,400	3,720
pH (SW9045)	5.57	6.38	4.99	4.84	5.79	5.32	5.17	6.03	6.80	6.25	8.26	4.57	6.65	5.99	5.75
Saturated pH	2.62	NA	4.7	NA	NA	4.6	4.8	NA	NA	NA	7.2	NA	6.1	NA	NA
% Moisture	25.6	15.4	9.1	17.6	13.7	21.0			13.9	19.2	15.4	22.4			
at: BAR 1/10	35.1	24.9	6.34	12.6	11.9	28.7	38.4	30.2	7.19	25.6	7.86	34.0	12.7	47.4	19.3
BAR 1/3	30.5	16.8	4.57	6.06	8.16	23.0	28.0	13.8	3.88	18.0	4.12	26.7	6.74	33.2	11.3
BAR 1	27.8	14.4	3.88	5.33	7.39	19.4	24.5	11.1	3.02	15.8	3.46	24.2	4.47	27.4	10.1
BAR 5	19.2	10.2	1.65	3.48	4.70	13.8	18.6	7.70	2.22	10.6	2.62	18.7	3.32	18.2	6.94
BAR 15	16.8	9.11	0.50	3.17	4.31	12.5	16.4	7.00	1.48	9.83	1.66	17.2	2.78	15.5	5.80
COMMENTS:			Oily, Sandy Matrix												
CATION EXCHANGE (meq/100g)	15.4	NA	NA	3.8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	N

GRAIN SIZE ANALYSIS

SIEVE ANALYSIS (Cumulative % Passing)

Particle Diameter (MM)	U.S. Standard Sieve Mesh															
2.0MM	#10	--	NA	NA	100	NA	100	NA	NA	NA	100	NA	100	100	NA	
.850MM	#20	99.7	NA	NA	99.7	NA	92.4	NA	NA	NA	99.1	NA	99.9	99.0	NA	9
.420MM	#40	99.0	NA	NA	97.3	NA	67.8	NA	NA	NA	84.9	NA	98.5	80.7	NA	9.

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TABLE H-1
PRE-CMS SOIL DATA COLLECTED DURING THE NAS, OCEANA RFI
December 1992 to February 1993

Sample Location		SITE 1				Site 2B				Site 2C				Site 2E		
		1-SB9	1-SB10	1-SB12	1-SB14	2B-SB5	2B-SB5	2B-SB1	2B-SB1	2C-SB2	2C-SB2	2C-SB3	2C-SB3	2E-SS6	2E-SS8	2E-SS10
.180MM	#80	95.6	NA	--	NA	NA	--	NA	NA	NA	--	NA	--	--	NA	68.5
.150MM	#100	95.1	NA	NA	85.5	NA	16.3	NA	NA	NA	50.2	NA	78.7	18.6	NA	51.5
.075	#200	92.4	NA	NA	83.2	NA	9.1	NA	NA	NA	48.6	NA	73.7	16.2	NA	35.7
0.075	#200	92.2	NA	NA	0	NA	0.0	NA	NA	NA	0.0	NA	0.0	0.0	NA	35.2
HYDROMETER ANALYSIS (% Soil Suspension)																
Particle Size (MM)	**Elapsed Time (Min.)**															
0.0615	0.67	NA	NA	NA	NA	22.4	NA	NA	NA	13.4	NA	13.4	NA	NA	79.1 A (0/0489)	33.0 A (0.0589)
0.0093	30	NA	NA	NA	NA	14.4	NA	NA	NA	8.4	NA	7.4	NA	NA	38.1 A (0.0086)	17.9 A (0.0092
0.0067	60	NA	NA	NA	NA	10.2	NA	NA	NA	5.2	NA	5.2	NA	NA	33.1 A (0.0062)	15.9 A (0.0066
0.0033	240	NA	NA	NA	NA	8.2	NA	NA	NA	4.2	NA	4.2	NA	NA	26.0 A (0.0031)	13.9 A (0.0033
0.0024	480	NA	NA	NA	NA	7.2	NA	NA	NA	4.2	NA	3.2	NA	NA	22.0 A (0.0023)	13.7 A (0.0023
0.0014	1440	NA	NA	NA	NA	7.2	NA	NA	NA	4.2	NA	3.2	NA	NA	16.4 A (0.0013)	11.7 A (0.0014

Notes:
NA - Not Analyzed
A - Particle Diameter Listed in Parentheses

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Table H-2
PRE-CMS GROUNDWATER DATA COLLECTED DURING THE NAS, OCEANA RFI
January 1993
(All data in mg/l except pH)

	Site 1		Site 2B			Site 2C			
	1-MW5	1-MW6	2B-MW3	2B-MW5	2B-MW6	2C-MW1	2C-MW4	2C-MW8	2C-MW12
TOC	10.9	8.7	11	26.4	14	NA	19	12.5	7.8
pH	6.5	7.5	NA	NA	NA	NA	NA	NA	NA
Hardness (as $CaCO^3$)	92	110	288	206	58	188	134	81	164
BOD, 5-day	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Oil and Grease	2.8	<0.1	NA	NA	NA	NA	NA	NA	NA
COD	24	28	NA	NA	NA	NA	NA	NA	NA
Alkalinity	115	115	296	300	94	325	183	70	150
P-Alkalinity	< 1	< 1	NA	NA	NA	NA	NA	NA	NA
Sulfate	16.0	12.6	NA	NA	NA	NA	NA	NA	NA
Chloride	14.9	24.3	NA	NA	NA	NA	NA	NA	NA
Sulfide	<0.1	<0.1	NA	NA	NA	NA	NA	NA	NA
Nitrate/Nitrite	<0.05	<0.05	NA	NA	NA	NA	NA	NA	NA

Notes:
NA - Not analyzed

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